P 96/990

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
Environmental Research Laboratories

Environmental Research Laboratories

Publication Abstracts

FY 1990

READEX FICHE best copy available

C 55.616:

U.S. DEPARTMENT OF COMMERCE
Robert A. Mosbacher, Secretary

National Oceanic and Atmospheric Administration
John A. Knauss, Under Secretary for
Oceans and Atmosphere/Administrator

Environmental Research Laboratories
Joseph O. Fletcher, Director

Environmental Research Laboratories

Publication Abstracts

FY 1990

October 1990
Boulder, Colorado

FOREWORD

As the research arm of the National Oceanic and Atmospheric Administration (NOAA), the Environmental Research Laboratories (ERL) support the present responsibilities and the development of future services of NOAA. Programs include investigation of ocean processes and their interactions with the atmosphere; studies of the ocean environment as it is affected by waste disposal and development of energy and food resources; fundamental studies of the upper atmosphere and space environments; atmosphere and ocean research on weather and climate change; research on severe local storms, hurricanes, and tsunamis; studies of cloud processes; research on the environmental effects of regional and global pollution; and development of equipment, instruments, systems, and facilities for these programs.

A principal measure of the success of a research laboratory is its output of scientific and technical papers and reports. The listings (including abstracts when available) in the following pages are an index of such ERL output for the period October 1, 1989, through September 30, 1990. This document includes all known articles published in journals for FY 1990 and those reports published within the official series of the Laboratories, as well as conference proceedings and other reports. It also includes publications by ERL-University cooperative institutes and by contractors funded by ERL.

Joseph O. Fletcher, Director
Environmental Research Laboratories
Boulder, Colorado

A GUIDE FOR USERS

Abstracts for this volume were submitted print ready by each Laboratory. If no abstract accompanied the original publication, the words "No abstract" follow the bibliographic entry.

Sections are arranged alphabetically by Laboratory. Some Laboratories have included an addendum listing publications inadvertently omitted from the FY 1989 volume.

Entries within the Laboratory sections are arranged alphabetically by author. ERL authors' names are typed in all capital letters.

An author index starts on p. 191. A guide for using the index is on p. 190.

Availability of Publications

Papers published in scientific and technical journals are available through the journals.

NOAA Technical Reports, Technical Memorandums, and Data Reports are available from

National Technical Information Service (NTIS)
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161
(703) 487-4600
FTS: Access code + 202 + 487-4600

The NTIS order number (if available at the time of publication of this document) is in parentheses following the report number in the bibliographic entry. Example: NOAA TM ERL ARL-119 (PB83-204347).

Questions may be addressed to

Programs Office, R/E1
National Oceanic and Atmospheric Administration
Environmental Research Laboratories
325 Broadway
Boulder, CO 80303
(303) 497-6212
FTS: Access Code + 320-6212

CONTENTS

	Index code*	Page
FOREWORD	--	iii
A GUIDE FOR USERS	--	iv
AERONOMY LABORATORY	AL	1
AIR RESOURCES LABORATORY	AR	30
ATLANTIC OCEANOGRAPHIC AND METEOROLOGICAL LABORATORY	AO	55
CLIMATE MONITORING AND DIAGNOSTICS LABORATORY	CM	69
FORECAST SYSTEMS LABORATORY	FS	87
GEOPHYSICAL FLUID DYNAMICS LABORATORY	GF	97
GREAT LAKES ENVIRONMENTAL RESEARCH LABORATORY	GL	106
NATIONAL SEVERE STORMS LABORATORY	NS	115
PACIFIC MARINE ENVIRONMENTAL LABORATORY	PM	125
SPACE ENVIRONMENT LABORATORY	SE	146
WAVE PROPAGATION LABORATORY	WP	159
APPENDIX: FEDERAL-STATE COOPERATIVE PROGRAM IN ATMOSPHERIC MODIFICATION RESEARCH	AP	182
ABOUT THE AUTHOR INDEX	--	190
AUTHOR INDEX	--	191

*See AUTHOR INDEX, p. 191.

ERL Publication Abstracts
FY 1990

AERONOMY LABORATORY

AL-001

ALBRITTON, D.L. The Greenhouse Effect: What we know; what we don't know. EPA Journal 16(2):4-7 (1990).

No abstract.

AL-002

ALBRITTON, D.L., N. Cobb, J.D. MAHLMAN, A.J. MILLER, J.T. PETERSON, W.G. Planet, and S. SOLOMON. Stratospheric ozone: The state of the science and NOAA's current and future research. U.S. Department of Commerce (1990).

No abstract.

AL-003

ALBRITTON, D.L., and R.T. Watson. NAS/NRC Committee on Global Change. EarthQuest 3(1):41 (1989).

No abstract.

AL-004

ALBRITTON, D.L., and R.T. Watson (Editors). Scientific assessment of stratospheric ozone: 1989, Vol. 1. World Meteorological Organization Global Ozone Research and Monitoring Project. Report No. 20 (1990).

The 1987 Montreal Protocol on Substances that Deplete the Ozone Layer called for convening four assessment panels. This document (Volume I) is the complete report of one of these panels (the Scientific Assessment Panel) convened under the Protocol's review provisions. In the Introduction to this report will be found details concerning the Montreal Protocol assessment and review procedures. This Introduction also contains overviews of the four chapters that comprise this assessment. Chapter 4 on halocarbon ozone depletion and global warming potentials has benefitted extensively from the scientific material and conclusions drawn from the Alternative Fluorocarbon Environmental Acceptability Study (AFEAS).

AL-005

ALBRITTON, D.L., and R.T. Watson. Stratospheric Ozone Revisited. EarthQuest 3(1):25 (1989).

No abstract.

AL-006

Anderson, J.G., W.H. Brune, and M.H. Proffitt. Ozone destruction by chlorine radicals within the Antarctic vortex: the spatial and temporal evolution of ClO-O_3 anticorrelation based on in situ ER-2 data. Journal of Geophysical Research 94(D9):11,465-11,479 (1989).

In situ O_3 and ClO data obtained from the ER-2 aircraft are used to define the chemical evolution of the Antarctic vortex region from August 23 to September 22, 1987. Initial conditions are characterized at aircraft flight altitude (18 km) by highly amplified ClO mixing ratios (800 parts per trillion by volume (pptv) within a well-defined "chemically perturbed region" (CPR) poleward of the circumpolar jet, within which ozone exhibits limited erosion (~15%) in middle to late August. Within this CPR, ozone decays consistently throughout the course of a 10-flight series, such that by late September, 75% of the O_3 has disappeared within the region of highly amplified ClO concentrations (which reached 500 times normal levels at ER-2 cruise altitude). As this ozone depletion develops, O_3 and ClO exhibit

dramatic negative correlation on isentropic surfaces, obtained as the aircraft passed through the edge of the CPR. Taken in conjunction with an analysis of the mechanisms defining the rate of catalytic O_3 destruction, it is concluded that ClO is an essential constituent in the catalytic destruction of ozone within the vortex. Therefore it is concluded that the observed disappearance of ozone within the Antarctic vortex would not have occurred in the absence of global chlorofluorocarbon release.

AL-007

Anderson, L.C., and D.W. FAHEY. Studies with $ClONO_2$: Thermal dissociation rate and catalytic conversion to NO Using and NO/O_3 chemiluminescence detector. Journal of Physical Chemistry (94):644-652 (1990).

A NO/O_3 chemiluminescence detector equipped with a gold catalyst is adapted to provide a measure of the thermal decomposition rate of $ClONO_2$ in an N_2/O_2 gas mixture and, in a related way, provide the absolute concentration of $ClONO_2$ in a flowing gas stream. The approach is to add $ClONO_2$, in the parts per million by volume (ppmv) range, to the flow stream of the detector in the presence of excess NO. As the sample is heated, $ClONO_2$ is thermally dissociated and the subsequent scavenging reaction of ClO with NO produces Cl and NO_2. Cl goes on to react with $ClONO_2$ to form NO_3 which, in turn, reacts with NO to produce NO_2. The loss of NO from the flow is precisely monitored downstream in the detector by the change in the chemiluminescence produced in the reaction of NO with reagent O_3. If the reaction rates with NO are given, the NO loss at a fixed temperature can be modeled to yield a dissociation rate constant for $ClONO_2$. Results were obtained for temperatures between 353 and 413 K and for pressures in the range of 66-160 Torr (8.8-21.3 kPa). The data is best fit by the expression $10^{-6.16}$ exp(-90.7 kJ mol^{-1}/RT) cm^3 s^{-1} molecule^{-1}, which is in good agreement with earlier results. When combined with the rate constant for the association reaction of ClO and NO_2, these results yield a larger equilibrium constant for the reaction than indicated in previous direct measurements. A value for $\Delta H^\circ_{289.15}$ for $ClONO_2$ of 22.9 kJ mol^{-1} is obtained from a third-law thermochemical analysis of the data. The initial $ClONO_2$ concentration in the sample is assumed to equal the absolute loss of NO measured when the dissociation and scavenging reactions have gone to completion. This affords the opportunity to calibrate the efficiency of other methods for the detection of $ClONO_2$. Results are presented for the conversion efficiency of $ClONC_2$ to NO found for a gold catalyst at 573 K with CO present as a reducing agent.

AL-008

Austin, J., R.L. Jones, D.S. McKenna, A.T. Buckland, J.G. Anderson, D.W. FAHEY, C.B. Farmer, L.E. Heidt, M.H. Proffitt, A.F. TUCK, and J.F. Vedder. Lagrangian photochemical modeling studies of the 1987 Antarctic spring vortex 2. Seasonal trends in ozone. Journal of Geophysical Research 94(D14):16,717-16,735 (1989).

A photochemical model consisting of 40 species and 107 reactions is integrated along 80 day air parcel trajectories calculated in the lower stratosphere for the springtime Antarctic. For the trajectory starting at 58°S, which may be regarded as outside the circumpolar vortex, only a small change in O_3 occurs in the model. In contrast, for the air parcel starting in the vortex at 74°S, the O_3 concentration is reduced by 93% during the 80 days from the beginning of August to late October. The model results for several species are compared with measurements from the Airborne Antarctic Ozone Experiment and, in general, good agreement is obtained. In the model, the denitrification of the air parcels in polar stratospheric clouds increases the amount of chlorine present in active form. Heterogeneous reactions maintain high active chlorine which destroys O_3 via the formation of the ClO dimer. Results of calculations with reduced concentrations of inorganic chlorine show considerably reduced O_3 destruction rates and compare favorably with the behavior of total O_3 since the late 1970s. The remaining major uncertainties in the photochemical aspects of the Antarctic ozone hole are highlighted.

AL-009

BALSLEY, B.B. Clear-air radar technology. Radar in Meteorology, 001-005 (1990).

No abstract.

AL-010

Bates, T.S., J.E. Johnson, P.K. Quinn, P.D. GOLDAN, W.C. KUSTER, D.C. Covert, and C.J. Hahn. The biogeochemical sulfur cycle in the marine boundary layer over the Northeast Pacific Ocean. Journal of Atmospheric Chemistry 10:59-81 (1990).

The major components of the marine boundary layer biogeochemical sulfur cycle were measured simultaneously onshore and off the coast of Washington State, U.S.A. during May 1987. Seawater dimethylsulfide (DMS) concentrations on the continental shelf were strongly influenced by coastal upwelling. Concentrations further offshore were typical of summer values (2.2 nmol/L) at this latitude. Although seawater DMS concentrations were high on the biologically productive continental shelf (2-12 nmol/L), this region had no measurable effect on atmospheric DMS concentrations. Atmospheric DMS concentrations (0.1-12 nmol/m^3), however, were extremely dependent upon wind speed and boundary layer height. Although there appeared to be an appreciable input of non-sea-salt sulfate to the marine boundary layer from the free troposphere, the local flux of DMS from the ocean to the atmosphere was sufficient to balance the remainder of the sulfur budget.

AL-011

Browell, E.V., C.F. Butler, S. Ismail, M.A. Fenn, S.A. Kooi, A.F. Carter, A.F. TUCK, O.B. Toon, M.H. Proffitt, M. Loewenstein M. R. Schoeberl, I. Isaksen, and G. Braathen. Airborne lidar observations in the wintertime Arctic stratosphere: ozone. Geophysical Research Letters 17(4):325-328 (1990).

Large-scale distributions of ozone (O_3) were measured with an airborne lidar system as part of the 1989 Airborne Arctic Stratospheric Expedition (AASE). Measurements of O_3 distributions were obtained between January 6 and February 15, 1989, on 15 long-range flights into the polar vortex from the Sola Air Station, Norway. The observed O_3 distribution was found to clearly indicate the edge of the polar vortex and to be an effective tracer of dynamical processes in the lower stratosphere. On the last two flights of the expedition, large regions with reduced O_3 levels were observed by the lidar inside the polar vortex. Ozone had decreased by as much as 17% in the center of these areas, and using the in situ measurements made on the ER-2 aircraft, it was concluded that this decline was due to chemical O_3 destruction.

AL-012

Browell, E.V., C.F. Butler, S. Ismail, P.A. Robinette, A.F. Carter, N.S. Higdon, O.B. Toon, M.R. Schoeberl, and A.F. TUCK. Airborne lidar observations in the wintertime Arctic stratosphere: polar stratospheric clouds. Geophysical Research Letters 17(4):385-388 (1990).

Polar stratospheric cloud (PSC) distributions in the wintertime Arctic stratosphere and their optical characteristics were measured with a multi-wavelength airborne lidar system as part of the 1989 Airborne Arctic Stratospheric Expedition. PSCs were observed on 10 flights between January 6 and February 2, 1989, into the polar vortex. The PSCs were found in the 14-27 km altitude range in regions where the temperatures were ≤195 K. Two types of aerosols with different optical characteristics (Types 1a and 1b) were observed in PSCs thought to be composed of nitric acid trihydrate. Type 1a PSCs typically exhibited low scattering ratios (1.2-1.5) and high aerosol depolarizations (30-50%) at 603 nm, while Type 1b PCSs had higher scattering ratios (3-8) and lower aerosol depolarizations (0.5-2.5%). Water ice PSCs (Type 2) were observed to have high scattering ratios (>10) and high aerosol depolarizations (>10%) at temperatures ≤190 K.

AL-013

Buhr, M.P., D.D. PARRISH, R.B. NORTON, F.C. FEHSENFELD, R.E. Sievers, and J.M. Roberts. Contribution of organic nitrates to the total reactive nitrogen budget at a rural eastern U.S. site. Journal of Geophysical Research 95:9809-9816 (1990).

Measurements of ambient levels of PAN (peroxyacetyl nitrate or, more properly, peroxyacetic nitric anhydride), C_2-C_5 alkyl nitrates, NO_x ($NO + NO_2$), HNO_3, and NO_3^- particulates were made concurrently with a measurement of total reactive nitrogen species (NO_y) at Scotia, Pennsylvania, from July 16 to August 31, 1988. Each of the organic nitrates exhibited a marked diurnal variation. The concentration of PAN varied from 0.05 to 3 ppbv (parts per billion by volume). The sum of the alkyl nitrate concentrations varied from less than 2 to 200 pptv (parts per trillion by volume). The NO_y levels varied from 1 to 30 ppbv. During periods of high photochemical activity the contributions to NO_y were 30-45% from HNO_3, 20-25% from PAN, 15-25% from NO_x, 5% from NO_3^-, and an additional 1.5% from the C_2-C_5 alkyl nitrates, on average. During these periods, about 15% of the measured NO_y could not be accounted for by the sum of the individually measured species. The unidentified species that constitute this 15% exhibit behavior similar to that of the measured organic nitrates.

AL-014

Burkholder, J.B., J.J. Orlando, and C.J. HOWARD. Ultraviolet absorption cross sections of Cl2O2 between 210 and 410 nm. Journal of Physical Chemistry 94:687-695 (1990).

The ultraviolet and infrared absorption cross sections of Cl_2O_2 have been measured. The transient Cl_2O_2 molecule was produced by using the gas-phase reaction $ClO + ClO + M \rightarrow Cl_2O_2 + M$. Three independent ClO radical source reactions were used in this study: $Cl + O_3$, $Cl + Cl_2O$, and $Cl + OClO$. The Cl_2O_2 UV absorption spectrum was recorded over the range 200-450 nm with a diode array spectrometer over the temperature range 205-250 K. The Cl_2O_2 infrared absorption spectrum was recorded with a high-resolution Fourier transform spectrometer over the range 500-2000 cm^{-1}. Both spectrometers were optically coupled to a fast flow multipass absorption cell. The UV absorption spectrum of Cl_2O_2 is a structureless continuum with a peak at 245 nm. The measurable absorption extends out to 410 nm. The UV absorption cross section at the peak of the spectrum, 245 nm, was measured to be $(6.5^{+0.8}_{-0.5}) \times 10^{-18}$ cm^2. Infrared absorption features centered at 560, 653, and 750 cm^{-1} have been assigned to the Cl_2O_2 molecule. The present results are compared with other reported UV and IR measurements and the sources of discrepancies are discussed. The role of Cl_2O_2 in atmospheric chemistry and in particular the Antarctic ozone "hole" are discussed.

AL-015

Burnett, E.B., C.R. Burnett, and K.R. Minschwaner. Periodic behaviors in the observed vertical column abundances of atmospheric hydroxyl. Geophysical Research Letters 16(11): 1,285-1,288 (1989).

OH vertical column abundances measured at Fritz Peak Observatory, Colorado, from 1977 through 1988 reveal semi-annual and annual cycles which are amplitude modulated over the 11-year data base. The modulation of the OH seasonal behavior is in phase with solar

activity as described by the sunspot number index. No mechanism for the observed covariance of this OH behavior with solar activity has yet been identified.

AL-016

CARROLL, M.A., D.R. Hastie, B.A. Ridley, M.O. Rodgers, A.L. Torres, D.D. Davis, J.D. Bradshaw, S.T. Sandholm, H.I. Schiff, D.R. Karecki, G.W. Harris, G.I. MacKay, G.L. Gregory, E.P. Condon, M. Trainer, G. Hübler, D.D. Montzka, S. Madronich, D.L. ALBRITTON, H.B. Singh, S.M. Beck, M.C. Shipham, and A.S. Bachmeier. Aircraft measurements of NO_x over the eastern Pacific and continental United States and implications for ozone production. Journal of Geophysical Research 95(D7):10,205-10,233 (1990).

Measurements of NO, NO_2, O_3, and CO are presented from 13 aircraft flights made over the eastern Pacific Ocean and the continental United States in August and September 1986 during the NASA GTE/CITE 2 program. Measurements of NO by three different groups (two different techniques) and of NO_2 by three different groups (three different techniques) are presented and examined along with calculated NO_x ($NO + NO_2$) for correlations with O_3, CO, and dew-point temperature (DPT) primarily as a function of air mass category. Median values of NO and NO_2) in the marine boundary layer were 4.0 and 10.4 pptv, respectively, and 12.4 and 18.0 pptv in the marine free troposphere. In the continental boundary layer, median values of NO and NO_2 were 34.5 and 75.0 pptv, respectively, and 13.0 and 36.0 pptv at altitudes above 3 km in air masses having continental influence. In the maritime NO_x data set a negative correlation is often observed between NO_x and DPT, while positive correlations were typically observed between NO_x and O_3 and between NO_x and CO. As expected, then, negative correlations were often observed between O_3 and DPT, and between CO and DPT, along with positive correlations between CO and O_3. In the continental data set, positive correlations were typically observed between NO_x and DPT, O_3, and CO. Additionally, the various air masses were examined with respect to regions of net ozone production or net ozone destruction. In all but one case in the marine boundary layer, model calculations indicate that there is significant ozone destruction. In the continental boundary layer, however, calculations indicate significant ozone production. In the middle free troposphere at 5± 1 km, the in situ ozone formation was most often nearly in balance with ozone destruction.

AL-017

CARROLL, M.A., D.D. Montzka, G. Hübler, K.K. KELLY, and G.L. Gregory. In situ measurements of NO_x in the airborne Arctic stratospheric expedition. Geophysical Research Letters 17(4):493-496 (1990).

In situ measurements of nitric oxide (NO) and nitrogen dioxide (NO_2) were made simultaneously from the NASA DC-8 aircraft as part of the Airborne Arctic Stratospheric Expedition. Mixing ratios of NO_x ($NO + NO_2$) were typically higher in the Arctic troposphere than in the stratosphere, with median values of 59 and 40 pptv, respectively. In the stratosphere, there tended to be a positive correlation between NO_x and water vapor (H_2O) and negative correlations between NO_x and ozone (O_3) and between NO_x and total reactive odd-nitrogen (NO_y). The ratio of NO_x to NO_y, in conjunction with NO_y, appears to be an excellent tracer of tropospheric or stratospheric air at northern latitudes during winter. Tropospheric NO_x was typically 10 to 50% of gas-phase NO_y, while in the stratosphere, NO_x was typically < 10%, and frequently <5% of gas-phase NO_y.

AL-018

CARROLL, M.A., R.W. Sanders, S. SOLOMON, and A.L. SCHMELTEKOPF. Visible and near-ultraviolet spectroscopy at McMurdo station, Antarctica 6. Observations of BrO. Journal of Geophysical Research 94(D14):16,633-16,638 (1989).

Observations of the evening twilight BrO abundance over McMurdo Station, Antarctia during austral spring, 1987, are described. The observed variation of the slant column abundance with increasing solar zenith angles suggests that most of the BrO is located near 15 km. The total vertical column abundance observed during 1 week of measurements yielded an average value of 2.5×10^{13} cm^{-2}, assuming the room temperature absorption cross sections measured by Cox et al. (1982). These values are consistent with BrO mixing ratios of about 5-15 parts per trillion by volume distributed from 150 to 20 mbar. If the differential absorption cross section of BrO increases by 30% at temperatures characteristic of the Antarctic lower stratosphere, as indicated by Sander and Watson (1981), then the BrO measurements reported in this paper should be decreased by 30%.

AL-019

Chameides, W.L., D.D. Davis, J. Bradshaw, S. Sandholm, M. Rodgers, B. Baum, B.Ridley, S. Madronich, M.A. CARROLL, G. Gregory, H.I. Schiff, D.R. Hastie, A.Torres, and E. Condon. Observed and model-calculated No_x/NO ratios in tropospheric air sampled during the NASA GTE/cite-2 field study. Journal of Geophysical Research 95(D7):10,235-10,247 (1990).

Data gathered during the NASA GTE/CITE 2 airborne field campaign were analyzed and compared with diagnostically derived parameters to study the No_x photostationary state in the troposphere and the processes that control this photostationary state. Our analysis focussed on two sets of No_2/No ratios derived from the data; these were based on overlapping NO and NO_2 measurements made by two independent techniques; i.e., a chemiluminescent technique and a technique based on two-photon, laser-induced fluorescence. While for any given 6- to 10-min time interval the two observed NO_2/NO ratios often exhibited significant discrepancies, these discrepancies appeared to be mostly random rather than systematic, and as a result, the average difference for all time intervals with overlapping No_x measurements was only 12%. One notable exception, however, was the block of data gathered during the last three CITE 2 missions; during these three missions

the ratios observed by the chemiluminescent technique were systematically larger than those observed by the laser-induced fluorescence technique by a factor of 1.6. When the data from these three missions were omitted from the analysis, the averages of the observed ratios agreed to within 1%. In contrast to a number of previous studies, the ratios predicted from photochemical model calculations were found to be reasonably consistent with the observed ratios, although on average they tended to fall about 20 - 25% below the observations. This agreement between observations and theory provides strong evidence in support of the importance of peroxy radicals in the fast photochemical cycling of NO_x (and the concomitant photochemical production of O_3) in both the marine and continental troposphere.

AL-020

Dester, G.D., C.H. Liu, S.J. Franke, and J.L. GREEN. Simultaneous observations of the troposphere and lower stratosphere by the flatland and Urbana ST radars: initial results. Handbook for MAP 28:439-445 (1989), Radio Science 25(5):917-931 (1990).

Simultaneous VHF radar observations of the troposphere and lower stratosphere were carried out on August 17-19, 1988 near Urbana, Illinois, using the Flatland radar and the Urbana stratosphere-troposphere (ST) radar, which are operated by the Aeronomy Laboratory of the National Oceanic and Atmospheric Administration and the University of Illinois Department of Electrical and Computer Engineering, respectively. The two radar sites are located on the vast plain area of central Illinois, separated by approximately 25 km. The geographical and observational configuration is considered most suitable for investigating mesoscale structures related to the tropopause, and another in the troposphere at about 8 km were observed at both radar sites for a long period of time. Velocity fluctuations with periods of 100 min <T<200 min were observed to be well correlated during a period of quiet horizontal wind. A convective thunderstorm on the evening of August 18 coincided with the dissipation of the tropospheric layer observed at 8 km. We present here a qualitative comparison of low-pass and band-pass filtered echo power and radial velocities, and a comparison of vertical power profiles from the two radars.

AL-021

Dominé, F., T.P. Murrells, and C.J. HOWARD. Kinetics of the reactions of NO_2 with CH_3S, CH_3SO, CH_3SS, and CH_3SSO at 297 K and 1 Torr. Journal of Physical Chemistry 94:5839-5847 (1990).

The rate constants for the reactions of NO_2 with CH_3S (1), CH_3SO (2), CH_3SS (3), CH_3SSO (4), have been measured at 297 K and 1 Torr in a discharge flow tube with photoionization mass spectrometric detection. The detection limits of the sulfur radicals studied were in the 10^{9} molecules cm^{-3} range. The rate constant values obtained are (in cm^3 $molecule^{-1}$ s^{-1}) $k_1 = (5.1 \pm 0.9) \times 10^{-11}$, $k_2 = (1.2 \pm 0.25) \times 10^{-11}$, $k_3 = (1.8 \pm 0.3) \times 10^{-11}$, $k_4 = (4.5 \pm 1.2) \times 10^{-12}$. The yield of CH_3SO in reaction 1 has been found to be unity. Curvature observed on some of the decay plots was attributed to the fragmentation of ions in the ionization chamber..

AL-022

Douglass, A.R., R.B. Rood, R.S. Stolarski, M.R. Schoeberl, M.H. Proffitt, J.J. Margitan, M. Loewenstein, J.R. Podolske, and S.E. Strahan. Global three-dimensional constituent fields derived from profile data. Geophysical Research Letters 17(4):525-528 (1990).

The success of 3D simulations of stratospheric constituent variability depends critically on the initialization of the constituent fields within the global model. We describe a technique for generating global 3D fields from vertical constituent profiles. The technique uses potential vorticity (q) and potential temperature (q) to map the profiles onto the global domain. The profiles used here are obtained from a 2D model calculation that reproduces the relationship between θ, q, N_2O and O_3 observed during the Airborne Arctic Stratospheric Expedition (AASE). The method is verified by comparison with satellite data, aircraft data and model simulations.

AL-023

Dye, J.E., B.W. Gandrud, D. Baumgardner, K.R. Chan, G.V. Ferry, M. Loewenstein, K.K. KELLY, and J.C. Wilson. Observed particle evolution in the polar stratospheric cloud of January 24, 1989. Geophysical Research Letters 17(4):413-416 (1990).

Particle size distributions measured from the NASA ER-2 with the new Forward Scattering Spectrometer Probe (FSSP) 300 in a type I polar stratospheric cloud (PSC) on January 24, 1989 show a volume mode near 0.8 μm diameter. The large increase in particle concentration and volume after cloud entry did not occur until the apparent saturation ratio of nitric acid with respect to nitric acid trihydrate reached 10, but at ratios near 1 subtle changes in the size distribution suggest some type I particles were present. Particle concentrations in cloud of 15 to 17 cm^{-3} were greater than the CN concentrations of 5 to 7 cm^{-3} just outside of cloud, suggesting nucleation on more than just sulfate particles. Some particles > 4 μm diameter were observed in a region which was saturated with respect to ice.

AL-024

ECKLUND, W.L., D.A. CARTER, B.B. BALSLEY, P.E. Currier, J.L. GREEN, B.L. WEBER, and K.S. GAGE. Field tests of a lower tropospheric wind profiler. Radio Science 25(5):899-906 (1990).

A small, portable 915-MHz wind-profiling Doppler radar has been developed at the National Oceanic and Atmospheric Administration's Aeronomy Laboratory. This radar provides high-resolution wind profiles from near the surface upward to 2-3 km in clear

air. Results of field trials in Colorado and Illinois are presented. These field trials include comparisons with 405-MHz and in very good agreement. Since the radar is very sensitive to heavy clouds and rain, it can be used to monitor the height of the melting layer and the vertical extent of hydrometeors. The small radar also provides temperature profiles up to 1 km when operated with an acoustic source in the radio acoustic sounding system (RASS) mode.

AL-025

FAHEY, D.W., S.R. Kawa, and K.R. Chan. Nitric oxide measurements in the Arctic winter stratosphere. Geophysical Research Letters 17(4):489-492 (1990).

Measurements of nitric oxide (NO) from five flights of the NASA ER-2 aircraft during the Airborne Arctic Stratospheric Expedition (AASE) are presented. The NO values and vertical gradient near 60°N latitude are similar to previous measurements near 50°N in winter [Ridley et al., 1984; 1987]. The NO latitudinal gradient is distinctly negative outside of the polar vortex, approaching zero at the boundary of the vortex, and remaining below the 20 pptv detection limit inside the vortex. The low NO values in the vortex occur at solar zenith angles as low at 82° indicating that NO_2 values in the vortex are also low. Steady state NO_2 and NO_x ($NO+NO_2$) are calculated from measured NO, O_3, and ClO, and modeled photodissociation rates. NO_x outside the vortex shows a negative dependence on latitude and solar zenith angle. The average ratio of NO_x to NO_y (at the same relative latitudes from different flight days) shows a strong latitude gradient with values near 0.08 at 12° equatorward of the vortex edge, decreasing to less than 0.02 at the vortex boundary. Low NO_x and NO_x/NO_y inside and near the vortex boundary may be indications of heterogeneous removal of $ClONO_2$ and N_2O_5.

AL-026

FAHEY, D.W., K.K. KELLY, G.V. Ferry, L.R. Poole, J.C. Wilson, D.M. MURPHY, M. Lowenstein, and K.R. Chan. In situ measurements of total reactive nitrogen, total water, and aerosol in a polar stratospheric cloud in the Antarctic. Journal of Geophysical Research 94(D9):11,299-11,315 (1989).

Measurements of total reactive nitrogen (NO_y), total water, and aerosol were made as part of the Airborne Antarctic Ozone Experiment during August and September 1987. The measurements were made using instruments located on board the NASA ER-2 aircraft, which conducted 12 flights over the Antarctic continent, reaching pressure altitudes of 20 km at 72°S latitude. The data presented here focus on a flight during which a polar stratospheric cloud (PSC) was encountered, containing concentrations of 0.8- to 2.6-μm diameter aerosol particles greater than 1 cm^{-3}. The temperatures in the cloud ranged as low as 184 K near 65-mbar pressure, but they remained above the frost point of water ice, except for short intervals. From knowledge of the vapor pressures over nitric acid condensates, the appearance of aerosol above the background level is consistent with the formation of the trihydrate phase, $HNO_3 3H_2O$. The anisokinetic feature of the NO_y sample probe enhances the concentration of large aerosol particles in the inlet by a factor of ~ 9. NO_y levels above 20 parts per billion by volume (ppbv) observed in the PSC indicate that aerosol NO_y species contribute substantially to the NO_y signal. The amount of aerosol $HNO_3 \cdot H_2O$ necessary to enhance the NO_y signal to observed levels is calculated from aerosol impaction theory and is found to be in satisfactory agreement with the observed aerosol volume. In addition, using the saturation vapor pressures and an estimate of available HNO_3 in the cloud, the predicted volume of $HNO_3 \cdot H_2O$ also shows satisfactory agreement with the directly measured aerosol volume. These results indicate that substantial aerosol volume containing HNO_3 and H_2O is formed at temperatures above the frost point in the Antarctic stratosphere in the winter and spring months. Such aerosol formation is thought to be the prerequisite for the production of active chlorine in heterogeneous reactions and for the large-scale removal of NO_y through aerosol sedimentations.

AL-027

FAHEY, D.W., K.K. KELLY, S.R. Kawa, A.F. TUCK, M. Lowenstein, K.R. Chan, and L.E. Heidt. Observations of denitrification and dehydration in the winter polar stratospheres. Nature 344(6264):321-324 (1990).

Water vapour and reactive nitrogen species are removed from the polar stratosphere in both hemispheres in the winter and early spring, probably by the sedimentation of aerosol particles containing water and nitric acid, which co-condense at low stratospheric temperatures. In the Antarctic in 1987, intense dehydration invariably accompanied intense denitrification. However, from the marked difference between water vapour concentrations in the two hemispheres for similar concentrations of reactive nitrogen, we deduce that in the Antarctic some dehydration may have occurred without denitrification. In the arctic in 1989, despite higher temperatures than in the Antarctic, intense denitrification occurred but without intense dehydration. These results provide important constraints for the uncertain microphysics controlling the growth and sedimentation of aerosol particles effecting the removal. We argue that the Arctic denitrification can be explained by the selective growth and sedimentation of aerosol particles rich in nitric acid. Because reactive nitrogen species moderate the destruction of ozone by chlorine-catalysed reactions, by sequestering chlorine in reservoir species such as $ClONO_2$, the possibility of the removal of reactive nitrogen without dehydration should be allowed for in attempts to model ozone depletion in the Arctic. Indeed, denitrification along with elevated concentrations of reactive chlorine observed in 1989 indicate that the Arctic was chemically primed for ozone destruction without an extended period of temperatures below the frost point, as is characteristic of the Antarctic.

AL-028

FAHEY, D.W., D.M. MURPHY, K.K. KELLY, M.K.W. Ko, M.H. Proffitt, C.S. Eubank, G.V. Ferry, M. Lowenstein, and K.R. Chan. Measurements of nitric oxide and total reactive nitrogen in the Antarctic stratosphere: observations and implications. Journal of Geophysical Research 94(D14):16,665-16,681 (1989).

Measurements of nitric oxide, NO, and the sum of reactive nitrogen species, NO_y, were made as part of the Airborne Antarctic Ozone Experiment (AAOE) on flights of the NASA ER-2 aircraft over the Antarctic continent. Reactive nitrogen species include NO, NO_2, NO_3, N_2O_5, HNO_3, and $ClONO_2$. The technique utilized the conversion of NO_y components to NO on a gold catalyst and the subsequent detection of NO by the chemiluminescent reaction of NO with O_3. NO was measured on two of the flights by removing the catalyst from the sample line. The flights ranged from 53°S to 72°S latitude in the lower stratosphere, with the majority of flights following the 425 K (± 10 K) or 450 K (± 10 K) potential temperature surfaces. The boundary of a chemically perturbed region (CPR) above the continent occurred on average near 66°S as indicated by a sharp increase in the level of ClO. Outside or equatorward of the CPR, No_y mixing ratios ranged between 6 and 12 parts per billion by volume (ppbv), with values increasing with latitude. At the edge of the CPR, large latitude gradients of NO_y and NO were found with values decreasing poleward. Total NO_y and NO were found with values decreasing poleward. Total NO_y levels dropped to 4 ppbv or less within 5° poleward of the boundary. NO values were 0.1-0.2 ppbv outside and below the detection limit of 0.03 ppbv inside the CPR. The levels of NO and NO_y observed preclude a chemical loss of ozone due to reaction with NO. The NO_y values outside the CPR are in accord with the results of two-dimensional photochemical models that incorporate only homogeneous chemistry when allowance is made for enhanced diabatic descent of air parcels. NO is somewhat lower than the model predictions. Inside the CPR, low NO_y values indicate denitrification, defined as the removal of NO_y from an air parcel. Low H_2O levels, which indicate dehydration, are observed to coincide with dentrification, suggesting that the respective processes are coupled. The partitioning of the remaining NO_y inside the CPR likely favors HNO_3 and $ClONO_2$. Outside the CPR, the concurrent measurements of ClO, NO, NO_y, and O_3 along with photochemical steady state relations indicate that NO_2 and $ClONO_2$ are minor NO_y components. Near the boundary, the variation of NO with ClO is shown to be consistent with heterogeneous reactions of HCl and $ClONO_2$ producing reactive chlorine.

AL-029

FAHEY, D.W., S. SOLOMON, S.R. KAWA, M. Loewenstein, J.R. Podolske, S.E. Strahan, and K.R. Chan. A diagnostic for denitrification in the winter polar stratospheres. Nature 345:698-699 (1990).

A striking negative correlation between *in situ* measurements of reactive nitrogen (NO_y) and nitrous oxide (N_2O) has been observed throughout the lower polar stratospheres[1,2]. This correlation has been extensively used to determine reference values for NO_y from a measurement of N_2O and, hence, to qualify the extent of denitrification in high-latitude air parcels[1,3]. (Denitrification in the atmosphere is defined as the permanent removal of reactive nitrogen.) The removal of NO_y from the Antarctic winter stratosphere maintains high concentrations of reactive chlorine, thereby priming the atmosphere for catalytic ozone destruction[4]. Here we present the pairwise correlation of the NO_y and N_2O data from the Southern and Northern Hemispheres. Both datasets show a linear correlation region, defined as a reference state, and regions of denitrification, where the correlation breaks down. Using two-dimensional photochemical model simulations of the atmosphere, we find a similar linear correlation between NO_y and N_2O, thereby establishing a theoretical framework for the reference state. This general approach, which can be extended to other pairs of molecules, should prove to be powerful in further comparisons of aircraft data with numerical models.

AL-30

FEHSENFELD, F.C., J.W. Drummond, U.K. Roychowdhury, P.J. Galvin, E.J. Williams, M.P. Buhr, D.D. PARRISH, G. Hübler, A.O. Langford, J.G. Calvert, B.A. Ridley, F. Grahek, B.G. Heikes, G.L. Kok, J.D. Shetter, J.G. Walega, C.M. Elsworth, R.B. NORTON, D.W. FAHEY, P.C. Murphy, C. Hovermale, V.A. Mohnen, K.L. Demerjian, G.I. Mackay, and H.I. Schiff. Intercomparison of NO_2 measurement techniques. Journal of Geophysical Research 95:3579-3597 (1990).

An intercomparison was made near Niwot Ridge, Colorado, of three different instruments for measuring NO_2 at low concentrations in ambient air: (1) the photolysis/chemiluminescence (PC) instrument, (2) the tunable diode laser absorption spectrometer (TDLAS), and (3) the Luminox instrument. Calibrated mixtures of NO_2 in air and NO_2 with possible interferants (HNO_3, peroxyacetyl nitrate (PAN), H_2O_2, n-propyl nitrate, and O_3) were provided in simultaneous tests. In addition, ambient air measurements were made using the three instruments. Blind procedures were followed in preparing all results. Several conclusions were reached concerning the performance of these instruments during this intercomparison: (1) For NO_2 levels above 2 parts per billion by volume (ppbv), similar results were obtained for all instruments; (2) Below 2 ppbv, the expected interferences from ozone and PAN influenced the NO_2 measurements made using the Luminox instruments. Those interferences were sufficiently consistent that they could be corrected for by using the measured values of O_3 and PAN down to about 0.3 ppbv NO_2; (3) The ozone interference on the Luminox instruments was removed by an ozone scrubber placed in the sampled air stream of the Luminox instrument. However, this did not remove PAN. In addition, the scrubber appeared to remove about 50% of the NO_2 as well; (4) Although no interferences were identified for the TDLAS technique, care must be taken in the data analysis near (or below) the detection limit for the instrument. At these levels the data reduction program provided with the TDLAS will tend to find background noise that is correlated with the reference NO_2 spectrum and calculate levels of NO_2 that are too high; (5) No interferences or artifacts were found for the final results reported by the PC technique. However, these results for ambient measurements were corrected by subtracting an artifact that averaged 5 parts per trillion by volume (pptv) and by calculating a correction for the effect of ambient ozone. This latter correction averaged 1.0% in magnitude.

AL-031

Fritts, D.C., T. Tsuda, T.E. VANZANDT, S.A. Smith, T. Sato, S. Fukao, and S. Kato. Studies of velocity fluctuations in the lower atmosphere using the MU radar. II: Momentum fluxes and energy densities. Journal of Atmospheric Sciences 47:51-66 (1990).

This paper describes a study of the frequency spectra, the vertical profiles of energy density, and the momentum flux of the motion field observed during a six-day campaign in March 1986 using the MU Radar in Shigaraki, Japan. Our results reveal significant differences between the mean zonal and meridional frequency spectra as well as different profiles of mean energy density with height for different frequency bands and for zonal and meridional components. The vertically averaged momentum flux exhibited considerable temporal variability and good consistency between adjacent beam pairs. A mean vertically averaged flux toward 267° was inferred, suggesting an essentially zonal drag in regions of wave dissipation. A mean frequency spectrum and height profiles of momentum flux in four frequency bands revealed a westward flux at all frequencies. Ratios of the difference to the mean variance of radial velocity in each vertical plane suggested an ~20%-30% excess of westward over eastward propagating wave energy as well as a significant contribution to the flux at low observed frequencies due to motions with high intrinsic frequencies. Inferred momentum flux profiles indicated largely zonal accelerations below the tropospheric jet and decelerations above.

AL-032

GAGE, K.S. Radar observations of the free atmosphere: Structure and dynamics. Radar in Meteorology, 534-574 (1990).

No abstract.

AL-033

GAGE, K.S. Recent developments in the application of wind-profiling doppler radars to tropical dynamics and climate research. International Geoscience and Remote Sensing Symposium, College Park, MD, May 20-24, 1990. Remote Sensing for the Nineties, 527-528 (1990).

This paper presents a summary of recent developments in the application of wind-profiling Doppler radars to tropical atmospheric research and climate monitoring. Recent technological developments in profiling wind temperature offer the potential for vastly improving our ability for observing the tropical atmosphere. Progress and plans for a trans-Pacific network of wind profilers are discussed in terms of the need to improve our understanding of the role of the tropics in global weather and climate

AL-034

GAGE, K.S., B.B. BALSLEY, W.L. ECKLUND, R.F. Woodman, and S.K. Avery. A trans-Pacific network of wind-profiling doppler radars for tropical dynamics and climate research. Proceedings of International Symposium on Equitoral Atmosphere Observations over Indonesia, Jakarta, March 6-7 (1990).

No abstract.

AL-035

GAGE, K.S., and G.D. Nastrom. A simple model for the enhanced frequency spectrum of vertical velocity based on tilting of atmospheric layers by lee waves. Radio Science 25(5):049-1057 (1990).

This paper is concerned with the interpretation of the enhanced frequency spectrum of vertical velocity that has been observed at many locations under strong-wind conditions in the vicinity of rough terrain. These enhanced frequency spectra are considerably more energetic .han the vertical velocity spectra observed under low-wind conditions, and their shape resembles the shape of the oblique spectra observed by the same radars. In this paper we present the composite spectra of horizontal and vertical velocity observed over a range of wind conditions by the Platteville, Colorado radar, located in the lee of the Colorado Rockies. The vertical velocity spectra clearly show the increase in magnitude and change in spectral slope that occurs as the troposphere becomes increasingly disturbed. We compare the observations with a simple model that relates the magnitude of the vertical velocity spectrum to the horizontal velocity spectrum and the effective tilt of atmospheric layers. Our results show that is possible to simulate the observed vertical velocity spectrum with effective tilts in the range of 2.5-10°. Recent observations of vertical velocity spectra from the Flatland radar, located in flat terrain in central Illinois, do not exhibit this behavior, which leads us to conclude that lee waves are responsible for the enhancement in the Colorado spectra.

AL-036

Gandrud, B.W., J.E. Dye, D. Baumgardner, G.V. Ferry, M. Loewenstein, K.R. Chan, L. Sanford, B. Gary, and K. KELLY. The January 30, 1989 Arctic polar stratospheric clouds (PSC) event: evidence for a mechanism of dehydration. Geophysical Research Letters 17(4):457-460 (1990).

In-situ particle measurements made aboard the NASA ER-2 in the Arctic on 890130 (YYMMDD) show Type 1 PSC particles over much of the flight, with instances of embedded Type 2 PSCs. The type 2 particles were observed at temperatures warmer than the local frost-point temperature of water; extended up to the upper size cutoff of the instrument (~ 24 μm diameter); and are shown to contain too large a volume to be primarily NAT. Based on measured vertical temperature profiles, we conclude that the Type 2 particles observed on this day were formed above the aircraft in a region where saturation with respect to ice was achieved and were sufficiently large to have fallen into the part of the ER-2. Although, the amount of material in the particles, expressed as water, is small by comparison to the total (vapor + aerosol) water concentration, the flux of water from the falling particles is of sufficient magnitude, if sustained, to lead to dehydration of the source region. These observations verify the mechanism for dehydration of polar vortex air masses by precipitation of ice particles.

AL-037

Gandrud, B.W., P.D. Sperry, L. Sanford, K.K. KELLY, G.V. Ferry, and K.R. Chan. Filter Measurement results from the airborne Antarctic ozone experiment. Journal of Geophysical Research 94(D9):11,285-11,297 (1989).

During the Airborne Antarctic Ozone Experiment (AAOE), filter samples were obtained for the determination of the total nitrate, sulfate, acidic chloride and acidic fluoride content along the flight path of the NASA ER-2. On three flights of the 12-flight series, filters were flown that allowed the separate but simultaneous collection of these species in the aerosol and vapor phase. The ratio of particulate sulfate observed outside the chemically perturbed region (CPR) of the vortex to that inside the CPR was 2.6. The total nitrate levels observed inside the CPR were less than those outside the CPR with one exception. The total nitrate levels observed inside the CPR decreased at a rate of 0.06 parts per billion by volume (ppbv) nitrate d^{-1} over the 36-day period of the measurements. Nitrate was observed in the particulate phase on two flights and was correlated with the coldest temperatures observed on the flights. Vapor phase nitrate within the CPR was measured on two flights and it ranged from 1.3 to 2.8 ppbv. Chloride and fluoride were not observed in the particulate phase at concentrations above the detection limits for those determinations. Total acidic fluoride was observed to be larger inside the CPR than outside in contrast to the other measured species. Ratios of total acidic chloride to total acidic fluoride observed at flight altitude exhibit values near 1, rather than the accepted mid-latitude value of 4-5, suggesting a loss of chloride from the reservoir species HCl and $ClONO_2$. The existence of larger amounts of total acidic fluoride inside the CPR compared to outside the CPR, coupled with the observation of less sulfate inside than outside suggests that the air inside the CPR had descended from a higher altitude.

AL-038

GOLDAN, P.D. Analysis of low-concentration-level gaseous sulfur compounds in the atmosphere. Standard Technical Publication 1052:114-132 (1990).

Intentional sulfur doping of the flame photometric detector results in a quasi-linear response with a linear dynamic range of ~100, a significantly reduced detection limit of ~3 pg of sulfur, and a graphic display of interferences caused by response quenching. The use of Teflon for all sample lines and valves is shown to result in significantly smaller analyte losses for several important volatile sulfur species including SO_2, CH_3SCH_3 [dimethyl sulfide (DMS)], and H_2S. Ozone interference is shown to be a major problem in the quantitation of ambient levels of DMS using both solid sorbant and cryogenic enrichment techniques. The relative merits of several ozone removal procedures are discussed.

AL-039

Golden, D.M., V.M. Bierbaum, and C.J. HOWARD. Comments on "Reevaluation of the Bond-Dissociation Energies (ΔH_{DBE}) for H-OH, H-OOH, H-O$^-$, H-O, H-OO$^-$, and H-OO". Journal of Physical Chemistry 94:5413-5415 (1990).

No abstract.

AL-040

Greenblatt, G.D., and A.R. RAVISHANKARA. Laboratory studies of the stratospheric NO_x production rate. Journal of Geophysical Research 95:3539-3547 (1990).

The chemistry of the production of NO in the stratosphere was examined in a two part study. First, the absolute quantum yield for the production of $NO(^2\Pi) + N(^4S)$ from N_2O photolysis at 193 nm was measured to be less than 8×10^{-3}. Second, in a new type of experiment, the yields of NO from the photolysis of N_2O at 193 nm in $N_2O/O_2/N_2$ and the photolysis of O_3 at 248 nm in $O_3/N_2O/O_2/N_2$ mixtures were measured. The measured yields showed excellent agreement with NO yields predicted from a model using previously measured rate

parameters. The results of this "integrated" experiment reduced the most probable uncertainty in the yield of NO from near 80% (calculated from the uncertainties in each individual step) to less than 30%.

AL-041

Gregory, G.L., J.M. Hoell, Jr., M.A. CARROLL, B.A. Ridley, D.D. Davis, J. Bradshaw, M.O. Rodgers, S.T. Sandholm, H.I. Schiff, D.R. Hastie, D.R. Karecki, G.I. MacKay, G.W. Harris, A.L. Torres, and A. Fried. An intercomparison of airborne nitrogen dioxide instruments. Journal of Geophysical Research 95(D7):10,103-10,127 (1990).

Results from an airborne intercomparison of techniques to measure tropospheric levels of nitrogen dioxide (NO_2) are discussed. The intercomparison was part of the National Aeronautics and Space Administration's Global Tropospheric Experiment and was conducted during the summer of 1986. Instruments intercompared included a two-photon nitric oxide (NO) laser-induced fluorescence system with laser photolysis of NO_2 to NO, an NO/O_3 chemiluminescence detector using $FeSO_4$ for conversion of NO_2 to NO, an NO/O_3 chemiluminescence detector with arc lamp photolysis of No_2 to NO, and a tunable diode laser multipath absorption system. All intercomparisons were for NO_2 mixing ratios of <200 pptv with most at mixing ratios of <100 pptv. The $FeSO_4$ converter was found to convert peroxyacetyl nitrate (PAN) to NO, resulting in NO_2 values a factor of 2-3 higher than reported by the other techniques. Thus the $FeSO_4$ converter data are excluded from the analyses. Intercomparison data were analyzed in various mixing ratio ranges. Good correlation was observed between the remaining three instruments for those data sets which included mixing ratios to 100 or 200 pptv, showing on the average a 30-40% level of agreement among the techniques. However, when the data were restricted to mixing ratios of <50 pptv, little correlation among the measurements was observed. Even though correlations were poor at mixing ratios of <50 pptv, the tunable diode laser system tended to be high compared to data reported by the two-photon laser and arc lamp chemiluminescence systems, and agreement between the latter two instruments was generally better than 20 pptv with an equal tendency for one to be high relative to the other.

AL-042

Gregory, G.L., J.M. Hoell, Jr., A.L. Torres, M.A. CARROLL, B.A. Ridley, M.O. Rodgers, J. Bradshaw, S. Sandholm, and D.D. Davis. An intercomparison of airborne nitric oxide measurements: a second opportunity. Journal of Geophysical Research 95(D7):10,129-10,138 (1990).

Results from an airborne intercomparison of techniques to measure tropospheric levels of NO are discussed. The intercomparison was part of the National Aeronautics and Space Administration's Global Tropospheric Experiment and was conducted during the summer of 1986. Instruments intercompared included a two-photon laser-induced fluorescence system and two NO/O_3 chemiluminescence detectors. These three instruments also participated in the NO intercomparisons conducted during the Chemical Instrumentation Test and Evaluation (CITE) 1 mission in 1983-1984, and therefore the current results are a revisit to the question of how well NO can be measured from an aircraft in remote tropospheric environments. The intercomparisons were weighed to mixing ratios less than 20 pptv. Results from CITE 2 were similar to those of CITE 1. The most noteworthy observation common to both campaigns is that at these low mixing ratios, agreement among the three instruments is almost always within about 15 or 20 pptv for sampling periods of 1-6 min. Analyses of multipoint data sets suggest that on the average the difference between data from any pair of the instruments at the low mixing ratios is about 5-7 pptv. Since this agreement was obtained among instruments using fundamentally different detection principles (chemiluminescent and laser) and the data suggested that all provided equally valid measurements of NO, the observed level of agreement perhaps represents the uncertainty in the current measurement of low mixing ratio ambient NO. The major question which must be addressed by the scientific community is the influence of, for example, a 5-pptv uncertainty in NO at 10 pptv in photochemistry studies, nitrogen budget studies, and so on, in the "clean" remote troposphere.

AL-043

Gregory, L.G., W.D. Hypes, L.S. Warren, A.F. TUCK, K.K. KELLY, and A.J. Krueger. Tropospheric ozone in the vicinity of the ozone hole: 1987 Airborne Antarctic Ozone Experiment. Journal of Geophysical Research 94(D14):16,537-16,545 (1989).

Tropospheric ozone measurements over Antarctica aboard the NASA DC-8 aircraft are summarized. As part of the August/September 1987 Airborne Antarctic Ozone Experiment, the aircraft flew 13 missions covering a latitude of 53°-90°S, at altitudes to 13 km. Ozone mixing ratios as high as several hundred parts per billion by volume (ppbv) were measured, but in all cases these ratios were observed in pockets or patches of upper atmospheric air. These pockets were observed both in the vicinity of and away from the location of the ozone hole, but they appeared to have occurred with higher frequency near or underneath the ozone hole. At times, and as a result of these pockets, the ozone levels at the flight altitude of the aircraft, as averaged beneath the boundaries of the stratospheric ozone hole, were 2-3 times higher than background tropospheric values. The data suggest that the ozone-rich air seldom penetrated below about 9-km altitude. Background ozone values in the surrounding troposphere were typically in the range of 20-50 ppbv. Correlation of tropospheric ozone observations with the boundaries of the ozone hole differed during the experiment. During the early flights (August 28 through September 2), encounters with ozone-rich air were limited and background tropospheric ozone (at the flight altitude) appeared to decrease beneath the hole. For many of the later flights, and as the hole deepened, the reverse was noted, in that ozone-rich air was frequently observed in the vicinity of the hole and, as noted earlier, average ozone at the flight altitude was frequently higher than background values.

AL-044

Hardy, K.R., and K.S. GAGE. The history of radar studies of the clear atmosphere. Radar in Meteorology , 130-142 (1990).

No abstract.

AL-045

Hoell, J.M., D.L. ALBRITTON, G.L. Gregory, R.J. McNeal, S.M. Beck, R.J. Bendura, and J.W. Drewry. Operational overview of NASA GTE/CITE 2 Airborne instrument comparisons: Nitrogen dioxide, nitric acid, and peroxyacetyl nitrate. Journal of Geophysical Research 95(D7):10047-10054 (1990).

This paper provides the rationale, objectives, approach, and a brief description of the instrumentation included in the second airborne Chemical Instrumentation Test and Evaluation (CITE 2) mission conducted by NASA. This mission, conducted on NASA's Electra aircraft, was based at Moffett Field, California, and intercompared data from instruments measuring NO_2, HNO_3, and PAN in the troposphere. Ancillary measurements augmented the intercomparison data in order to address specific questions related to the budget and partitioning of odd nitrogen species in the troposphere. This study, conducted in August 1986, encountered marine and continental air with free tropospheric mixing ratios of NO_2, HNO_3, and PAN typically less than 120, 150, and 200 parts pet trillion by volume, respectively. Other papers in this issue provide the detailed results of the intercomparison tests and also discuss issues related to the budget and distribution of oddi nitrogen species in the troposphere.

AL-046

Hooke, W.H., D.L. ALBRITTON, R.E. Carbone, T. Gal-Chen, C.W. Kreitzberg, C.G. Little, and H. Tennekes. Report of the Critical Review Panel--Lower Tropospheric Profiling Symposium: Needs and Technologies. Bulletin of the American Meteorological Society, 71(5):680-690 (1990).

No abstract.

AL-047

Hübler, G., D.W. FAHEY, K.K. KELLY, D.D. MONTZKA, M.A. CARROLL, A.F. TUCK, L.E. Heidt, W.H. Pollock, G.L. Gregory, and J.F. Vedder. Redistribution of reactive odd nitrogen in the lower Arctic stratosphere. Geophysical Research Letters 17:453-456 (1990).

In-situ measurements of total reactive odd nitrogen (NO_y) were made from the NASA DC-8 aircraft in the lower Arctic stratosphere during the 1989 Airborne Arctic Stratospheric Expedition. Throughout January and February, NO_y mixing ratios were typically between 0.5 and 3 parts per billion by volume (ppbv) at altitudes between 10 and 12.5 km. During several flights late in the mission, events of unusually high NO_y occurred with mixing ratios up to 12 ppbv at these altitudes. Simultaneous measurements of N_2O, O_3, and H_2O during these events suggest that large changes in NO_y are not expected. The elevated NO_y values are interpreted as a vertical redistribution of NO_y in the lower stratosphere resulting from gravitational sedimentation of aerosol particles containing HNO_3. No evidence of the redistribution of H_2O is noted consistent with observations of denitrification without dehydration higher in the stratosphere.

AL-048

Huebert, B.J., S.E. Vanbramer, P.J. LeBel, S.A. Vay, A.L. Torres, H.I. Schiff, D. Hastie, G. Hübler, J.D. Bradshaw, M.A. CARROLL, D.D. Davis, B.A. Ridley, M.O. Rodgers, S.T. Sandholm, and S. Dorris. Measurements of the nitric acid to NO_x ratio in the troposphere. Journal of Geophysical Research 95:10,193-10,198 (1990).

Nitric acid concentrations, measured by both Teflon/nylon filter packs (FP) and the tungstic oxide denuder (DEN), are compared with the average NO_x concentrations from laser-induced fluorescent and chemiluminescent methods. The HNO_3/NO_x ratio based on filter packs ranged from 0.8 to 10.4, with a mean of 3.4. The DEN nitric acid concentrations produced ratios ranging from <0.3 to 9.8, with a mean of 2.6. Average marine ratios were larger than those from continental regions, in part due to continental anthropogenic sources of NO_x. Although we collected very few boundary layer samples, their average ratios were smaller than those in the free troposphere, apparently because of the effect of dry surface removal of nitric acid. The nitric acid to NO_x ratio was greatest when the NO_x/NO_y ratio was smallest, such that the nitrogen photochemistry was nearing completion.

AL-049

Jones, R.L., J. Austin, D.S. McKenna, J.G. Anderson, D.W. FAHEY, C.B. Farmer, L.E. Heidt, K.K. KELLY, D.M. MURPHY, M.H. Proffitt, A.F. TUCK, and J.F. Vedder. Lagrangian photochemical modeling studies of the 1987 Antarctic spring vortex 1. comparison with AAOE observations. Journal of Geophysical Research 94(D9): 11,529-11,558 (1989).

In this paper, results from a photochemical model integrated along ensembles of 8-day air parcel trajectories are used to simulate the

latitude and vertical composition gradients observed from the ER-2 aircraft during the 1987 Airborne Arctic Ozone Experiment (AAOE). The photochemical model used includes heterogeneous chemical reactions when polar stratospheric clouds are inferred, from local temperature and pressure, to be present. The model results were found to be very sensitive to No_y mixing ratios and the frequency of polar stratospheric clouds (PSCs). Trajectories often showed instantaneous (adiabatic) cooling rates of up to 30 K d^{-1}, with air parcels even at high latitudes spending substantial periods outside modeled clouds. This leads to a photochemical "balance" in the model calculations between the perturbations to the composition caused by the heterogeneous reactions and the restoring effects of HNO_3 destruction. For the period of interest (early September 1987), the model was able to simulate well both the latitude gradient of ClO on the 428 K potential temperature surface and the ClO vertical gradient at 72° S. The model simulated well the NO and NO_y concentrations at high latitudes inside the dehydrated, denitrified region, although NO values outside were significantly overestimated. There is evidence from the chlorine and the nitrogen species partitioning in the model that even outside the denitrified, dehydrated region the chemical composition is perturbed. It is argued that heterogeneous processing on type I PSCs has occurred in this outer region, but without denitrification or dehydration. Model results imply that the BrO observations made from the ER-2 within the dehydrated, denitrified region are consistent with there being approximately 5 parts per trillion by volume of BrO_y at 428 K in spring. Within the high ClO region, ozone destruction rates are calculated to exceed 2% d^{-1} with approximately 80% due to the ClO dimer mechanism.

AL-050

Jones, R.L., D.S. McKenna, L.R. Poole, and S. SOLOMON. On the influence of polar stratospheric cloud formation on chemical composition during the 1988/89 Arctic winter. Geophysical Research Letters 17(4):545-548 (1990).

The northern winter polar vortex is more disturbed dynamically and warmer than the Antarctic equivalent, and correspondingly fewer polar stratospheric clouds (PSCs) are observed to form. However, the rapid flow of stratospheric air through slow moving synoptically forced PSC regions can result in exposure of both vortical and extra vortical air to PSCs intermittently throughout the winter months. This periodic exposure to PSCs may be sufficient to perturb the chemical composition of large volumes of northern hemisphere air. The synoptic forcing also leads to marked meridional flow which has a profound effect on chemical composition, having major impacts on both short term ozone depletion and the longer term recovery to lower ClOx abundances. Accurate simulation of the air flow is thus essential for the reliable calculation of ozone loss in polar regions.

AL-051

Jones, R.L., D.S. McKenna, L.R. Poole, and S. SOLOMON. Simulating the evolution of the chemical composition of the 1988/89 winter vortex. Geophysical Research Letters 17(4):549-552 (1990).

During the 1988/89 Airborne Arctic Stratospheric Expedition (AASE) observations of the chemical composition and aerosol characteristic of the winter vortex were obtained from a NASA ER-2 aircraft. In this paper we present interpretations of observations obtained on three ER-2 flights using a Lagrangian coupled photochemical-microphysical model. It is argued that observations obtained on January 16 and 19, and February 10, represent different stages of the chemical evolution of the vortex, from the early stages of chlorine release, the onset of denitrification and the intensively processed state.

AL-052

Jones, R.L., S. SOLOMON, D.S. McKenna, L.R. Poole, W.H. Brune, D.W. Toohey, J.G. Anderson, and D.W. FAHEY. The polar stratospheric cloud event of January 24: Part 2, Photochemistry. Geophysical Research Letters 17(4):541-544 (1990).

During the 1988/89 Airborne Arctic Stratospheric Expedition (AASE), observations of the chemical composition, aerosol characteristics and atmospheric state were obtained from two aircraft, a NASA ER-2 and a DC-8. In this paper we present a diagnosis of observations obtained using the ER-2 on January 24, 1989, using a Lagrangian coupled microphysical-photochemical model. We interpret the high chlorine monoxide mixing ratios observed from the ER-2 on the afternoon of January 24, 1989 as a result of in-situ heterogeneous release of reactive chlorine from the reservoirs HCl and $ClONO_2$ on type 1 polar stratospheric cloud particles observed to be present at that time. This essential element in theories of polar ozone depletion has never before been observed directly in the stratosphere.

AL-053

Kawa, S.R., D.W. FAHEY, L.C. Anderson, M. Lowenstein, and K.R. Chan. Measurements of total reactive nitrogen during the airborne Arctic stratospheric expedition. Geophysical Research Letters 17(4):485-488 (1990).

Composite distributions of measured total reactive nitrogen (NO_y) from the NASA ER-2 during the Airborne Arctic Stratospheric Expedition (AASE) are presented. The observed features of these distributions are discussed in terms of the controlling dynamical, chemical, and microphysical processes. In the latitudinal profile from 58°N to within about 4° poleward of the polar vortex boundary, NO_y conforms closely to predictions of NO_y based on N_2O measurements. The features of the distribution are apparently dynamically controlled. Poleward of 5° of latitude within the boundary, the average NO_y decreases sharply and is significantly lower than that predicted from N_2O. This feature is consistent with loss of NO_y through sedimentation of particles containing NO_y in polar stratospheric clouds.

The observed loss is not as systematic as in the Antarctic, consistent with the observed differences in season and meteorological conditions between the two campaigns.

AL-054

KELLY, K.K., and A.F. TUCK. A comparison of ER-2 measurements of stratospheric water vapor between the 1987 Antarctic and 1989 Arctic airborne missions. Geophysical Research Letters 17(4):465-468 (1990).

Vertical profiles of water vapor inside the Antarctic vortex have been compared with those taken outside it over Punta Arenas (53°S, 71°W). A similar exercise was performed with Arctic vortex profiles and those taken over Stavanger (59°N, 6°E). Residual water, defined as the stratospheric water vapor mixing ratio with the contribution from methane oxidation subtracted, is also shown as profiles inside and outside the vortex for both missions. The Arctic and Antarctic profiles of water vapor and residual water are compared. Locally dehydrated air was evident both inside and outside the Antarctic vortex, but such dehydration was not evident in and around the Arctic vortex. Arctic profiles of residual water are consistent with non-tropical entry for some air.

AL-055

KELLY, K.K., A.F. TUCK, D.M. MURPHY, M.H. Proffitt, D.W. FAHEY, R.L. Jones, D.S. McKenna, M. Loewenstein, J.R. Podolske, S.E. Strahan, G.V. Ferry, K.R. Chan, J.F. Vedder, G.L. Gregory, W.D. Hypes, M.P. McCormick, E.V. Browell, and L.E. Heidt. Dehydration in the lower Antarctic stratosphere during late winter and early spring, 1987. Journal of Geophysical Research 94(D9):11,317-11,357 (1989).

Measurements of total water were made with Lyman α resonance florescence hygrometers mounted on the ER-2 and DC-8 aircraft. Direct evidence was obtained for dehydration of the lower stratosphere over Antarctica; minimum values were about 1.5 parts per million by volume (ppmv), compared with values of 3.0 4.5 ppmv immediately outside the region high potential vorticity gradient in the potential temperature range $420 < \theta < 460$ K. On one flight, ice crystals large enough to have appreciable sedimentation velocities were observed. The DC-8 data at $300 < \theta < 320$ K frequently showed extensive belts of dry, ozone-rich air between 60° and 75°S latitude, with the equatorward "edge" in water well correlated with that observed by the ER-2 some 8-9 km higher. Data from near Punta Arenas and from the ferry flights are used to argue that the effects of dehydration over Antarctica were visible at mid-latitudes.

AL-056

Ko, M.K.W., J.M. Rodriguez, N.D. Sze, M.H. Proffitt, W.L. Starr, A. Krueger, E.V. Browell, and M.P. McCormick. Implications of AAOE observations for proposed chemical explanations of the seasonal and interannual behavior of Antarctic ozone. Journal of Geophysical of Research 94(D14):16,705-16,715 (1989).

A number of numerical experiments using different assumptions on the initial odd nitrogen content and the efficiencies and durations of heterogeneous reactions is selected based on the simulations of the observed trace gas concentrations during the Airborne Antarctic Ozone Experiment (AAOE) in 1987 (Rodriguez et al., this issue). The model is used to calculate the seasonal behavior of O_3 in 1987 and its possible interannual variations as the chlorine content of the atmosphere increases from 1 to 6 ppbv. The seasonal behavior in 1987 is compared with the total ozone mapping spectrometer (TOMS) and AAOE data. In all the cases considered, the catalytic cycle associated with the formation and photolysis of Cl_2O_2 could account for more than half of the photochemical removal of O_3 within the Antarctic vortex through mid-September. The reaction of BrO with ClO, which accounts for 15-20% of the removal in the same period, tends to play a more important role toward the end of September, when the concentration of ClO is expected to decrease. The detailed behavior of the calculated O_3 depends on the assumptions for the spatial and temporal extent of denitrification, the initial concentrations of odd nitrogen species sequestered in the vortex in July, and the efficiencies and duration of the heterogeneous reactions in the months that follow. Additional observations of ClO, odd nitrogen species, and O_3 similar to those obtained in the campaign covering the period in July and October will be useful in providing additional constraints to narrow down the possibilities. There is no simple relationship between the increase in chlorine level and the interannual decrease in Antarctic O_3. It is difficult to explain both the 40% decrease in October mean O_3 within the hole since 1979 and the much slower decrease prior to the mid-1970s without invoking effects from interannual variations of heterogeneous activities and initial odd nitrogen concentrations in July. Such effects must be isolated before the observed trends in the Antarctic O_3 hole in the past 8 years can be used to predict future behavior of O_3 based solely on projected increase in the chlorine content of the atmosphere.

AL-057

Kondo, Y., P. Aimedieu, W.A. Matthews, D.W. FAHEY, D.G. Murcray, D.J. Hofmann, P.V. Johnston, Y. Iwasaka, A. Iwata, and W.R. Sheldon. Balloon-borne measurements of total reactive nitrogen, nitric acid, and aerosol in the cold Arctic stratosphere. Geophysical Research Letters 17(4):437-440 (1990).

Total reactive nitrogen (NO_y) between 15 and 29 km was measured for the first time on board a balloon within the Arctic cold vortex. Observations of HNO_3, aerosol, and ozone were made by instruments on the same balloon gondola which was launched from Esrange,

Sweden (68°N, 20°E) on January 23, 1989. The NO_y mixing ratio was observed to increase very rapidly from 6 ppbv at 18 km altitude to a maximum of 21 ppbv at 21 km, forming a sharp layer with a thickness of about 2 km. A minimum in the NO_y mixing ratio of 5 ppbv was found at 27 km. The measured HNO_3 profile shows broad similarities to that of NO_y. This observation, together with the observed very low column amount of NO_2, shows that NO_x had been almost totally converted to HNO_3, and that NO_y was composed mainly of HNO_3. The enhanced aerosol concentration between 19 and 22 km suggests that the maximum abundance of HNO_3 trapped in the form of nitric acid trihydradt (NAT) was about 6 ppbv at 21 km. The sampled air parcels were highly supersaturated with respect to NAT. Although extensive denitrification throughout the stratosphere did not prevail, an indication of denitrification was found at altitudes of 27 and 22 km, and between 18 and 15 km.

AL-058

Lait, R.L., M.R. Schoeberl, P.A. Newman, M.H. Proffitt, M. Loewenstein, J.R. Podolske. S.E. Strahan, K.R. Chan, B. Gary, J.J. Margitan, E. Browell, M.P. McCormick, and A. Torres. Reconstruction of O_3 and N_2O fields from ER-2, DC-8, and balloon observations. Geophysical Research Letters 17(4):521-524 (1990).

Measurements of N_2O and O_3 during the Airborne Arctic Stratospheric Expedition have been composited using the potential vorticity and potential temperature of each measurement as coordinates. For ozone, data sources included the ER-2 and balloon ozonesonde *in situ* measurements, DC-8 DIAL lidar, and SAGE satellite profiles. For N_2O, only ER-2 data were used. These chemical composites have been reconstructed onto average meteorological fields for the mission in a latitude-altitude cross-section, yielding a picture of the chemical composition of the polar vortex during this period. Tracers inside the vortex show an apparent descent of about 2 km relative to those outside, resulting in an apparent chemical edge on isentropic and isobaric surfaces.

AL-059

Liu, C-M, S.C. LIU, and S-H, Shen. A study of Taipei ozone problem. Atmospheric Environment 24A(6):1,461-1,472 (1990).

A high level of ozone has been a serious problem in Taipei. At one station there were concentrations of hourly O_3 127 and 60 time > 120 ppbv in 1986 and 1987, respectively. The diurnal O_3 varriation is mainly governed by a single-peaked (SP) pattern with a major peak near noontime, and a double-peaked (DP) pattern with a primary peak near noontime and a secondary peak in the early morning. The analyses of observed NO_x, NO_2 and NMHC distributions suggest that the photochemical production of ozone is responsible for the primary peak but not the secondary peak. In January, DP occurs more frequently than SP, while in June the SP pattern dominates. Analyses of the surface meteorological data suggest that a unique localized circulation may be responsible for the occurrence of the secondary peak of the DP pattern. A simplified quasi-three-dimensional model is developed to analyze the effect of land-sea breeze on the temporal and spatial variation of O_3.

AL-060

Lovejoy, E.R., K.S. Kroeger, and A.R. RAVISHANKARA. The kinetics of the $CS_2OD + O_2$ reaction. Chemical Physics Letters 167:183-187 (1990).

Rate coefficients for the CS_2OH and $CS_2OD + O_2$ reactions were measured by monitoring OH and OD in excess CS_2, as a function of $[O_2]$ and time. The rate coefficient for $CS_2OD + O_2$ was $(2.3\pm0.4) \times 10^{-14}$ cm^3 molecule^{-1} s^{-1} in 50 Torr He at 273 K. No kinetic isotope effect was observed ($k_H/k_D = 1.05\pm0.18$) suggesting that the reaction mechanism is not direct H atom abstraction by O_2. Rate coefficients for OH and OD ($A\ ^2\Sigma^+$) + CS_2 were also measured and found to be equal.

AL-061

Lovejoy, E.R., T.P. Murrells, A.R. RAVISHANKARA, and C.J. HOWARD. Oxidation of CS_2 by reaction with OH. 2. Yields of HO_2 and SO_2 in oxygen. Journal of Physical Chemistry 94:2386-2393 (1990).

The products of the OH-initiated oxidation of CS_2 have been investigated. Analysis of the OH loss and the HS production using a laser magnetic resonance (LMR) discharge-flow apparatus yielded $k_1 < 3 \times 10^{-15}$ cm^3 molecule^{-1} s^{-1} for the reaction $OH + CS_2 \rightarrow HS + OCS$ (1) (340 K and 5 Torr (He)). The oxidation of CS_2 is enhanced by O_2 due to the following mechanism: $OH + CS_2 \underset{\leftarrow}{\rightarrow} CS_2OH$ (2), and $CS_2OH + O_2 \rightarrow$ products (3). HO_2 was identified by LMR detection as a major product from this chemistry. The HO_2 yield was measured in a pulsed photolysis experiment by modeling OH temporal profiles with NO added to convert HO_2 to OH. The HO_2 yield was 95 ± 20% of the OH consumed by reactions 2 and 3 leads to SO_2 production.

AL-062

Margitan, J.J., G.A. Brothers, E.V. Browell, D. Cariolle, M.T. Coffey, J.C. Farman, C.B. Farmer, G.L. Gregory, J.W. Harder, D.J. Hofmann, W. Hypes, S. Ismail, R.O. JAKOUBEK, W. Komhyr, S. Kooi, A.J. Krueger, J.C. Larsen, W. Mankin, M.P. McCormick, G.H. MOUNT, M.H. Proffitt, A.R. RAVISHANKARA, A.L. SCHMELTEKOPF, W.L. Starr, G.C. Toon, A. Torres, A.F. TUCK, A. Wahner, and I. Watterson. Intercomparison of ozone measurements over Antarctica. Journal of Geophysical Research 94(D14):16,557-16,569 (1989).

Measurements of the abundances of ozone over Antarctica in August and September 1987 obtained during the Airborne Antarctica Ozone Experiment are intercompared. These measurements of ozone concentrations and total column abundance were obtained by three satellite instruments, two IR and one UV column-measuring instruments aboard the DC-8, one in situ DC-8, and two in situ ER-2 instruments, an upward looking lidar aboard the DC-8, and ozonesondes from four sites in Antarctica. Given the natural variability of ozone in the Antarctic and the fact that the data were not truly coincident spatially and temporally, this intercomparison is suitable only for identifying gross disparities among the techniques, rather than confirming the accuracies as rigorously as is normally done in an intercomparison. This paper presents a summary of the ozone data, using the data and accuracies given by the individual investigators in the individual papers in this issue, without any attempt to critically review or evaluate the data. In general, very good agreement (within about 10-20%, limited by natural variability) among the various techniques was found, with no systematic biases detected. These observations confirm the low ozone amounts reported in the Antarctic stratosphere.

AL-063

MAY, P.T., R. G. STRAUCH, K.P. MORAN, and W.L. ECKLUND. Temperature sounding by RASS with wind profiler radars: A preliminary study. IEEE Transactions on Geoscience and Remote Sensing 28(1):19-28 (1990).

RASS (Radio Acoustic Sounding System) is a method of remotely measuring atmospheric temperature of profiles by combining acoustic and radar techniques. This method has been applied to wind profiler radars in Colorado, and excellent performance in both height coverage and accuracy has been obtained. Various acoustic source functions are examined, and it is shown that FM-CW acoustic signals are less susceptible to error than pulsed acoustic systems when using pulsed radars for RASS. The remotely determined temperature profiles are compared with co-located radiosonde soundings and good agreement is found.

AL-064

MCAFEE, J.R., K.S. GAGE, B.B. BALSLEY, W.L. ECKLUND, D.A. CARTER, and G.C. REID. Intraseasonal oscillations in the upper troposphere observed with the Christmas Island wind profiler. Proceedings of the 14th Annual Climate Diagnostics Workshop, La Jolla, California, 132-133 (1989).

No abstract.

AL-065

McKeen, S.A., M. Trainer, E.Y. Hsie, R.K. Tallamraju, and S.C. LIU. On the indirect determination of atmospheric OH radical concentrations from reactive hydrocarbon measurements. Journal of Geophysical Research 95(D6):7,493-7,500 (1990).

Measurements of nonmethane hydrocarbons (NMHCs) from urban plumes have previously been used to deduce average OH concentrations by monitoring the decay of the NMHCs from initial values and comparing their time rates of decay to the decay rate of a relatively inert tracer emitted from the same source. Under the assumption of no interaction between photochemistry and transport, these observationally derive indirect OH concentrations are lower for NMHCs with successively higher reactivities toward OH. In this study, analytical solutions to simple flow situations and a three-dimensional mesoscale model are used to test this assumption. When turbulent transport is parameterized in terms of diffusion coefficients, the models yield results that are consistent with the observations and suggest that the assumption is not generally valid. Daytime vertical mixing within the planetary boundary layer (PBL) and horizontal diffusion are two transport processes that cannot be assumed to be separable from species reactivity. The net effect is that under most daytime conditions the OH concentrations can be underpredicted by more than a factor of 2 when highly reactive NMHCs are used to derive OH concentrations in the usual manner. However, these results only apply when the species used to derive OH concentrations are emitted from a continuous source. The assumption of separability between photochemistry and transport is valid when only instantaneous or puff emissions are considered. An explanation of these effects is presented within the context of the analytical results to some simple flow system. Results from the three-dimensional model are used to illustrate the interaction of species reactivity and transport for more realistic parameterizations of atmospheric transport. The results of this study have important implications for experiments designed to indirectly determine OH concentrations and also for the treatment of turbulent transport in Lagrangian and Eulerian photochemical models.

AL-066

McKeen, S., D. Kley, and A. Volz. The historical trend of tropospheric ozone over western Europe: A model perspective. In Ozone in the Atmosphere. (R.D. Bojkov, and P. Fabian (eds.). Deepak Publishing, 552-556 (1989).

Annual mean ozone mixing ratios in the late nineteenth and early twentieth centuries measured near Paris, France were between 5 and 15 ppbv (Volz and Kley, 1988), while present day average mixing ratios are typically greater than 25 ppbv for remote locations in western Europe. The increase of NO_x and non-methane hydrocarbon (NMHC) emissions from anthropogenic activity over this time period is known to be a determining factor in regard to this increase. In this study, a one-dimensional model of the troposphere is used to construct a time history of surface ozone for conditions applicable to summertime in western Europe. The model incorporates a high resolution, diurnally varying planetary boundary layer, stratospheric sources of ozone and NO_y, and surface emissions from natural and anthropogenic sources of NO_x and NMHC. Results of the model are reasonably consistent with recently observed increases in surface ozone at two European stations. The low concentrations observed in the beginning of this century are reproduced accurately only if biogenic emissions of NMHC are included, and if currently recommended mechanisms of the NMHC oxidation process are invoked. Surface fluxes and concentrations of NO_x that, if exceeded, lead to net tropospheric ozone production are also determined, and are also found to be sensitive to natural NMHC emissions and assumed oxidation pathways. Formation of ozone and other photochemical oxidants from estimates of present day NO_x and NMHC emissions are also discussed.

AL-067

McKellar, A.R.W., M. Vervloet, J.B. Burkholder, and C.J. HOWARD. A combined analysis of the ν_1, ν_3, and $2\nu_2$ vibrational states of the NH_2 radical using Fourier transform absorption and emission data. Journal of Molecular Spectroscopy 142:319-335 (1990).

The ν_3 ($\tilde{}$3301 cm^{-1}) and ν_1 ($\tilde{}$3219 cm^{-1}) fundamental bands of NH_2 have been measured at high resolution using a Fourier transform (FT) infrared spectrometer and a fast-flow multiple-traversal absorption cell. Extensive information in the form of combination differences has been obtained for the nearby $2\nu_2$ ($\tilde{}$2961 cm^{-1}) state from emission spectra in the visible and near-infrared regions that were also recorded using an FT spectrometer. The absorption and emission data were combined in order to perform the first simultaneous least-squares fit of the interacting ($\nu_1\nu_2\nu_3$) = (001), (100), and (020) vibrational states of NH_2. The analysis shows that extensive Coriolis mixing of (001) and (100) occurs for some rotational levels starting with $N \geq 4$ and that effects of the anharmonic (Fermi-type) mixing of (100) and (020) are evident for certain levels with $N \geq 6$. The magnitude of the (100)-(020) anharmonic interaction parameter is found to be 28.85 cm^{-1}, which is somewhat smaller than the value of 47.9 cm^{-1} found in the similar molecule H_2O. The molecular parameters and calculated energy levels obtained here for NH_2 give an accurate characterization of the rotational energy levels for (100) and (020) up to $N = 9$ and $K_a = 8$, and for (001) up to $N = 7$, $K_a = 4$.

AL-068

McKenna, D.S., R.L. Jones, A.T. Buckland, J. Austin, A F. TUCK, R.H. WINKLER, and K.R. Chan. The Southern Hemisphere lower stratosphere during August and September 1987: analyses based on the United Kingdom Meteorological Office Global Model. Journal of Geophysical Research 94(D14):16,874-16,854 (1989).

The main object of this paper is to present in one place a series of meteorological analyses to aid the interpretation of the in situ Airborne Antarctic Ozone Experiment (AAOE) observations. Maps and sections of meteorological variables derived from the United Kingdom Meteorological Office global model are presented for ER-2 and DC-8 flight days. Analyzed temperatures and winds are generally in good agreement with AAOE observations at all levels. Minor discrepancies in winds and temperatures are evident, particularly at DC-8 altitudes, and are discussed in the paper. Model analyses show temperatures at 60°W cold enough to saturate water at 1 part per million by volume as late as September 14 and that following that date a sudden increase in the temperature at all levels within the vortex precludes further saturation at low water vapor mixing ratios. Maps of potential vorticity are presented on the 428-K potential temperature surface for the AAOE flight days. These show that the vortex is essentially circumpolar although there are periods when major distortions are apparent. At the 428-K potential temperature level, the area of the vortex, as defined by the areas enclosed by selected potential vorticity contours, remains approximately constant throughout the AAOE.

AL-069

McKenna, D.S., R.L. Jones, L.R. Poole, S. SOLOMON, D.W. FAHEY, K.K. KELLY, M.H. Proffitt, W.H. Brune, M. Loewenstein, and K.R. Chan. Calculations of ozone destruction during the 1988/89 Arctic winter. Geophysical Research Letters 17(4):553-556 (1990).

Calculations of ozone depletion during the 1988/89 Arctic winter using a Lagrangian coupled photochemical-microphysical model are presented in this paper. Abundances of ClO in excess of 1 ppbv were observed at the end of the Airborne Arctic Stratospheric Expedition (AASE) on February 10, 1989. These are shown to be consistent with the removal of more than 90% of the reactive nitrogen and the conversion of more than 80% of reservoir chlorine to active forms. This chemical state implies that ozone losses of more than 20 ppbv per day can be sustained in heavily denitrified air throughout much of February according to current photochemistry. As much as 74% of the loss is calculated to be due to ClO dimer photolysis. Following the warming of the vortex in mid February 1989, ozone loss through ClO dimer photolysis becomes less effective as the rate of thermal decomposition of the ClO dimer increases. Thus, model results suggest that thermal decomposition of the dimer plays an important role in limiting ozone loss in the Arctic spring.

AL-070

MURPHY, D.M. Time offsets and power spectra of the ER-2 data set from the 1987 airborne Antarctic ozone experiment. Journal of Geophysical Research 94(D14):16,737-16,748 (1989).

The time offsets and power spectra of the data taken from the ER-2 during the 1987 Airborne Antarctic Ozone Experiment (AAOE) are described. All of the ER-2 data appear to be aligned in time to within ±5 s. Power spectra for most of the chemical species and meteorological conditions measured from the ER-2 show clear transitions from white noise to atmospheric variability. All data except that from the ozone instruments showed noise at frequencies above 0.1 Hz, corresponding to length scales below 2 km. The pressure, temperature, and wind data reported by the meteorological measurement and navigation recorder systems are consistent with each other, with pressures generally within 2%, wind speeds within 15% and temperatures differing by <1K.

AL-071

MURPHY, D.M., K.K. KELLY, A.F. TUCK, and M.H. Proffitt. Ice saturation at the tropopause observed from the ER-2 aircraft. Geophysical Research Letters 17(4):353-356 (1990).

Ice saturation at or just above the tropopause was frequently observed during the ER-2 vertical profiles over Stavanger (59°) during the Airborne Arctic Stratospheric Expedition (AASE). On occasion, ice saturation extended as much as 500 m above the tropopause. Saturation was not observed over Punta Arenas (53°S) during the Airborne Antarctic Ozone Experiment (AAOE). Saturation extending just above the tropopause was observed at Moffett Field (38°N) in winter but not in summer. The top of a thick cirrus layer at the tropopause will be very strongly cooled, and a thin cloud layer at the tropopause will either be strongly heated or cooled depending on the presence of lower level clouds. Some ER-2 data suggest removal of water and nitrogen species from the tropopause.

AL-072

Murrells, T.P., E.R. Lovejoy, and A.R. RAVISHANKARA. Oxidation of CS_2 by reaction with OH: 1. Equilibrium constant for the reaction $OH + CS_2 \rightleftarrows CS_2OH$ and the kinetics of the $CS_2OH + O_2$ reaction. Journal of Physical Chemistry 94:2381-2386 (1990).

The reaction of OH with CS_2 was studied in He (50 Torr), N_2 (9-40 Torr), and SF_6 (30-60 Torr) over the temperature range 249-318 K by using pulsed laser photolysis to generate OH and pulsed-laser-induced fluorescence to detect OH. The rapid approach of [OH] to equilibrium was observed at each temperature, indicating reversible formation of a CS_2OH adduct. Analysis of the [OH] temporal profiles provided the rate coefficients for the forward and reverse components of the reaction $OH + CS_2 + M \rightleftarrows CS_2OH + M$ and, hence, the equilibrium constant. The temperature dependence of the equilibrium constant yielded the heat of reaction, $\Delta H^\circ_{298} = -10.9 \pm 1.0$ kcal mol^{-1} and the entropy change for the reaction, $\Delta S^\circ_{298} = -24.0 \pm 4.4$ cal K^{-1} mol^{-1}. No evidence could be found for a direct non-adduct-forming channel for the OH + CS_2 reaction leading to $k(OH + CS_2 \rightarrow \text{products}) \leq 2 \times 10^{-15}$ cm^3 molecule^{-1} s^{-1}. An enhancement by O_2 of the OH loss rate in CS_2 was observed, confirming the occurrence of a reaction between CS_2OH and O_2. Analysis of the [OH] temporal profiles gave a rate coefficient for the $CS_2OH + O_2$ reaction of $(2.6 \pm 1.0) \times 10^{-14}$ cm^3 molecule^{-1} s^{-1} which was independent of temperature from 249 to 299 K.

AL-073

Nastrom, G.D., and K.S. GAGE. Enhanced frequency spectra of winds at the mesoscale based on radar profiler observations. Radio Science 25(5):1039-1047 (1990).

Frequency spectra of horizontal winds based on the radar profilers at Poker Flat, Alaska, and Platteville, Colorado, are studied over the range of periods from about 10 min to a day. At Platteville in the troposphere the spectrum of both zonal and meridional winds is found to obey a power law dependence on frequency at periods longer than a few hours. At shorter periods the spectra show a transition to a second power law regime which has enhanced energy relative to a simple extrapolation of the curve which fits the low-frequency regime. The magnitude of the enhancement is about a factor of 4. The slope of the spectrum in both regions appears to be near -5/3. In the transition region, between periods of about 1/2 and 2 1/2 hours, the spectrum appears to follow a slope near -1. At Poker Flat, where useful results extend to about 20 km, a similar pattern is found in the stratosphere, above 10 km, except that the magnitude of the enhancement factor is about 1.7. This two-regime model is found to be robust, applying when the results are sorted by season, background wind speed, altitude, and total variance under the spectrum. The results are discussed in terms of a spectrum of vertically propagating gravity waves launched by flow over rough terrain, and the implications for a spectrum due to stratified turbulence are considered.

AL-074

Nastrom, G.D., K.S. GAGE, and W.L. ECKLUND. Uncertainties in estimates of the mean vertical velocity from MST radar observations. Radio Science 25(5):933-940 (1990).

Mean values of the vertical velocity based on time series of clear-air Doppler radar observations are subject to uncertainties due to several factors. This paper examines the statistical uncertainties due to estimating the population means using only finite periods of

record and the uncertainties that are introduced by systematic gaps in the series of observations. The statistical uncertainty, the standard error of the mean, depends on the variance of the data and on the effective sample size. The largest change in the variance of vertical velocity is about a factor of 3 and is seen between clear and cloudy sky conditions. Very little change in the effective sample size is seen under any conditions. The averaging time required to estimate the mean with a standard error of the mean of 2 cm/s is found to be about 6 hours under typical conditions at Flatland. The uncertainty of the mean due to systematic gaps in the data increases with the length of the gaps, even though the total observation period remains constant. The root-mean-square value of this uncertainty is about 2 cm/s; about the size of the standard error of the mean and about half as large as typical expected subsynoptic scale motions. These results suggest that future sampling programs should be designed to eliminate systematic gaps in the data.

AL-075

Nastrom, G.D., J. L. GREEN, M.R. Peterson, and K.S. GAGE. Tropopause folding and the variability of the tropopause height as seen by the flatland VHF radar. Journal of Applied Meteorology 28:1272-1281 (1989).

The Flatland radar, a VHF wind profiler located near Urbana, Illinois, has been used to study the variability of the tropopause over the period March 1987-April 1988. The vertically directed radar beam provides an indicator of tropopause height as well as measurements of the vertical velocity of the air. The sudden tropopause height changes previously seen in special campaigns are found to be relatively common features. Several case studies made under varying synoptic conditions are used to show that these discontinuities are associated with tropopause folding events as revealed by cross-section analysis of potential temperature and potential vorticity based on radiosonde data. The vertical velocity in a typical tropopause fold is downward at up to 15 cm s^{-1}. Finally, applications of the continuous data from VHF radars to develop quantitative climatologies of tropopause folding events are presented.

AL-076

Nastrom, G.D., M.R. Peterson, J.L. GREEN, K.S. GAGE, and T.E. VANZANDT. Sources of gravity waves as seen in the vertical velocities measured by the Flatland VHF radar. Journal of Applied Meteorology 29(8):783-792 (1990).

Observations of vertical velocity made with the Flatland VHF radar located in the extremely flat terrain near Champaign, Illinois, are used to study sources of enhanced variance. The variance is used as an indicator of gravity wave activity. In contrast to sites in or near mountains where lee wave activity often masks signals due to other sources, at Flatland we find that all episodes of enhanced variance are correlated with synoptic or mesoscale weather events, such as the passage of fronts or jet streams and convection. Case studies are used to characterize the sources of variance in the data, with specific examples from the spring of 1987. Also, summaries from data collected over the entire period March 1987 through May 1988 are presented. It is found that largest variances of vertical velocity are associated with low stability in the lower troposphere; most often indicated by clouds and convection and less frequently due to a dynamic feature such as strong winds or a front. It is found that wave activity is about 50% greater in the troposphere and lower stratosphere in the cloudy skies ahead of midlatitude storm systems than in the clear skies above the stable air behind storms.

AL-077

PARRISH, D.D., M.P. Buhr, R.B. NORTON, M. Trainer, and F.C. FEHSENFELD. Photochemical interconversions of odd-nitrogen species at a rural, eastern U.S. site. Proceedings, International Conference on Global and Regional Environmental Atmospheric Chemistry, Beijing, China, May 3-10, 1989. DOE, 122-127 (1990).

Extended abstract.

AL-078

PARRISH, D.D., C.H. Hahn, D.W. FAHEY, E.J. Williams, M.J. Bollinger, G. Hübler, M.P. Buhr, P.C. Murphy, M. Trainer, E.Y. Hsie, S.C. LIU, and F.C. FEHSENFELD. Systematic variations in the concentration of NO_x (NO plus NO_2) at Niwot Ridge, Colorado. Journal of Geophysical Research 95:1817-1836 (1990).

Measurements of the concentrations of NO and NO_2 were made in the rural troposphere during a year's period in 1980-1981, during the summers of 1983, 1984, and 1987, and during the fall of 1984. The field site was located near Niwot Ridge, Colorado, at an elevation of 3 km. NO was measured with a chemiluminescence instrument, and NO_2 was photolyzed to NO and measured by the same instrument. The performance of this instrument is discussed in detail. Aspects of the NO_x (sum of NO and NO_2) concentrations discussed include the overall distribution, the seasonal and diurnal cycles, the interannual variations, and the correlation with meteorological parameters. The meteorological dependence of $[NO_x]$ elucidates the mechanisms that transport NO_x to the site. Even though the Denver urban area lies downwind from the site with respect to the prevailing winds, it is NO_x from that area that predominates and is responsible for the enhanced acidic deposition and elevated ozone levels at the site. The valley-mountain flow that is primarily responsible for this transport also may be an important mechanism for transporting anthropogenic pollution from the planetary boundary layer to the free troposphere. The major photochemical loss processes of NO_x are reaction of NO_2 with hydroxyl radicals to form HNO_3 and the formation of PAN (peroxyacetyl nitrate) and perhaps other organic nitrates in the summer and reaction of NO_2 with O_3 to form NO_3, N_2O_5, and further oxidized species in the winter.

AL-079

Perliski, L., and J. London. Satellite observed long-term averaged seasonal and spatial ozone variations in the stratosphere. Planetary Space Science 37(12):1,509-1,525 (1989).

Nine years of *Nimbus*-7 SBUV ozone mixing ratio data (October 1978-September 1987) have been used to analyze the distrubutions of the long-term average annual and semi-annual ozone oscillations in the lower, middle, and upper stratosphere over the region 65°S to 65°N. It is shown that the derived harmonics are consistent with the results of earlier investigations based on limited sets of data. Year-to-year changes of amplitudes of the annual and semi-annual variations are generally small except in the tropical midstratosphere (due to the effect of El Chichon) and the southern distribution of the zonal ozone variations. Analyses are also presented to show the vertical and seasonal distribtuion of the zonal ozone variations. It is shown that, for the long-term averaged data, wave 1 is larger during winter than summer and in winter larger in the Northern than Southern Hemisphere. The importance of photochemical and thermal/dynamic processes in modifying the time and zonal variations is discussed.

AL-080

Perliski, L.M., S. SOLOMON, and J. London. On the interpretation of seasonal variations of stratospheric ozone. Planetary Space Science 37(12):1,527-1,538 (1989).

Insight into the causes of the annual and semi-annual ozone oscillations may be gained from the analysis of photochemical model behavior. In this paper, the monthly variations of the ozone mixing ratio computed by the two-dimensional photochemical model of Garcia and Solomon (1983, *J. Geophys. Res.* 88, 1379) are Fourier-analyzed and compared with SBUV observations of ozone mixing ratio. Remarkably good qualitative agreement between the model calculations and the observations is found. Analysis of computed transport and chemical production and destruction rates reveals the causes of the modelled seasonal ozone variations. It will be shown that at high latitudes and low altitudes, modelled ozone abundances increase in the winter due to transport and decrease in the summer due to chemical destruction. In the middle stratosphere, the calculated annual ozone variation is largely due to the annual variation in the odd-oxygen production rate, and in the upper stratosphere, the computed annual ozone variation is caused by the large calculated annual oscillation in temperature. Comparison between the model and observations suggests that the equatorial semi-annual oscillation above 10 mb is caused mainly by the semi-annual temperature and wind oscillation (SAO). Below 10 mb the computed equatorial ozone variation is caused by the increased rates of odd-oxygen production associated with the semi-annual zenith crossings of the Sun. Finally, the calculated polar semi-annual ozone oscillations are found to be caused by modulation of the radiatively-driven middle-stratospheric ozone variation by temperature dependent chemical destruction processes.

AL-081

Poole, L.R., S. SOLOMON, B.W. Gandrud, K.A. Powell, J.E. Dye, R.L. Jones, and D.S. McKenna. The polar stratospheric cloud event of January 24, 1989, Part 1. Microphysics. Geophysical Research Letters 17(4):537-540 (1990).

Rapid adiabatic cooling induced by synoptic forcing led to polar stratospheric cloud (PSC) formation on January 24, 1989, at altitudes sampled by the ER-2 aircraft. Particle characteristics measured by the Forward Scattering Spectrometer Probe (FSSP) on the ER-2 were compared to those calculated using a theoretical PSC microphysics model. Although calculations were sensitive to local changes in cooling rate, generally favorable agreement was found, that in particle surface area being especially important since this parameter dictates heterogeneous chemical rates. The overall model performance suggests that the current approach for simulating type 1 (nitric acid trihydrate) PSC formation under rapid cooling conditions is well founded and can be used to study the effects of heterogeneous chemistry on stratospheric composition.

AL-082

Poole, L.R., S. SOLOMON, M.P. McCormick, and M.C. Pitts. The interannual variability of polar stratospheric clouds and related parameters in Antarctica during September and October. Geophysical Research Letters 16(10):1,157-1,160 (1989).

Antarctic polar stratospheric cloud (PSC) sightings by the orbiting SAM II sensor during September and October show a pronounced Quasi-Biennial Oscillation (QBO) signal, and October sightings have increased markedly over the past 10 years in years of westerly QBO phase. The QBO in PSC frequency is likely to affect the rate of Antarctic heterogeneous chemical processes and, hence, ozone depletion. Studies of the observed long-term temperature trend suggest that the decadal PSC trend probably results from the ozone decline through its effect on stratospheric heating rates. A more detailed analysis of data from 1986 and 1987 shows that there were more PSCs in 1987 and that they persisted much later into the spring season as compared to 1986. Qaulitatively similar behavior was found for the OC1O column abundances and 18-km ozone depletion observed at McMurdo Station during these 2 years. These observations suggest that both the intensity and duration of heterogeneous chemical processes are likely greater during colder, QBO-westerly phase years.

AL-083

Proffitt, H.M., D.W. FAHEY, K.K. KELLY, and A.F. TUCK. High-latitude ozone loss outside the Antarctic ozone hole. Nature 342(6247):233-237 (1989).

Data taken during the 1987 Antarctic Airborne Ozone Experiment based in Punta Arenas, Chile, are used to show that from mid-August until the end of the mission in late September there was a high-latitude ozone loss outside the Antarctic ozone hole. Therefore, not only is the geographic extent of the ozone loss larger than that generally identified as chemically perturbed, but ozone is lost earlier in the year than previously reported. These results, when compared with long-term temporal trends of column ozone, indicate a possible anthropogenic component for this loss.

AL-084

Proffitt, M.H., K.K. KELLY, and J.A. Powell. Evidence for diabatic cooling and poleward transport within and around the 1987 Antarctic ozone hole. Journal of Geophysical Research 94(D14):16,797-16,813 (1989).

Combining in situ measurements of nitrous oxide, total water, and NO_y with meteorological data, including potential vorticity, taken during the 1987 Airborne Antarctic Ozone Experiment, a consistent picture emerges of a gradual poleward movement of air extending from about 10° in latitude outside the boundary of the ozone hole to about 5° inside. The data analysis is concentrated in the potential temperature range of 425-450 K, corresponding to geometric altitudes of 17.5-19 km. Evidence of ongoing diabatic cooling throughout this region is presented, and cooling rates of about 1.75 K in potential temperature per day (approximately 0.8 K per day in temperature at constant pressure) are calculated from the data outside the boundary of the ozone hole. An interpretation of the data is presented that describes the movement of air that has come from lower latitudes into the ozone hole, as diabatically descending and spiraling poleward. The result of this spiraling motion is a dominantly advective flow of ozone rich air across the boundary and into the ozone hole. This simple picture precludes requiring extensive isentropic mixing with accompanying vertical descent to maintain the steep poleward isentropic gradients found in nitrous oxide. Data are presented to show that the necessary accompanying outflow of stratospheric air from within the ozone hole occurs at potential temperatures less than 42[illegible] K and that, during the mission, there was no significant transport of processed air across the boundary and out of the ozone hole from 425 to 450 K. Arguments involving conservation of angular momentum are also used to support this model.

AL-085

Proffitt, M.H., J.J. Margitan, K.K. KELLY, M. Loewenstein, J.R. Podolske, and K.R. Chan. Ozone loss in the Arctic polar vortex inferred from high-altitude aircraft measurements. Nature 347:31-36 (1990).

The Arctic polar vortex in winter is known to be chemically primed for ozone depletion, yet it does not exhibit the large seasonal ozone decrease that characterizes its southern counterpart. This difference may be due in part to a net flux of ozone-rich air through the Arctic vortex, which can mask ozone loss. But by using a chemically conserved tracer as a reference, significant ozone loss can be identified. This loss is found to be correlated with high levels of chlorine monoxide, suggesting that much of the decrease in ozone is caused by anthropogenic emissions of chlorofluorocarbons.

AL-086

Proffitt, M.H., J.A. Powell, A.F. TUCK, D.W. FAHEY, K.K. KELLY, A.J. Krueger, M.R. Schoeberl, B.L. Gary, J.J. Margitan, K.R. Chan, M. Loewenstein, and J.R. Podolske. A chemical definition of the boundary of the Antarctic ozone hole. Journal of Geophysical Research 94(D9):11,437-11,448 (1989).

A campaign utilizing an ER-2 high-altitude aircraft and a DC-8 aircraft, both fitted with state-of-the-art instrumentation to study the Antarctic ozone hole, was conducted out of Punta Arenas, Chile, from August 17 through September 22, 1987. Data indicated a chemically perturbed region roughly coincident with the Antarctic polar vortex and with the region of large temporal decrease of ozone that is usually referred to as the Antarctic ozone hole. A rapid rise in ClO was observed as the ER-2 proceeded into the ozone hole at about 18 km altitude, and it is this feature that is used to define the boundary of the chemically perturbed region as that latitude along the flight track where ClO reaches 130 parts per trillion by volume (pptv). In situ data taken simultaneously aboard the ER-2, as well as Total Ozone Mapping Spectrometer (TOMS) satellite ozone data along the flight tracks, are analyzed at fixed positions relative to this boundary and are presented as averages over the duration of the mission. These analyses indicate a narrow transition zone at the boundary for the chemically active species ClO, O_3, NO_y, and NO. A somewhat wider transition zone for the chemical species N_2O and H_2O and for the meteorological parameters of temperature, wind speed, and potential vorticity is also seen, indicating the dynamical character of the chemically defined boundary. TOMS column values of about 260 Dobson units (DU) generally persisted at the boundary during this period. One-month temporal trends of the in situ data both inside and outside this boundary are also presented. Interpretations of these analyses are offered that are consistent with ongoing diabatic cooling, accompanying advective poleward transport across the boundary. These data strongly implicate man's release of chlorine into the atmosphere as a necessary ingredient in the formation of the Antarctic ozone hole.

AL-087

Proffitt, M.H., M.J. Steinkamp, J.A. Powell, R.J. MCLAUGHLIN, O.A.. MILLS, A.L. SCHMELTEKOPF, T.L. THOMPSON, A.F. TUCK, T. TYLER, and R.H. WINKLER. In situ ozone measurements within the 1987 Antarctic ozone hole from a high-altitude ER-2 aircraft. Journal of Geophysical Research 94(D14):16,547-16,555 (1989).

In situ ozone measurements were made from the ER-2 aircraft during the 1987 Airborne Antarctic Ozone Experiment both inside and outside the ozone hole. Midday measurements from late August until late September during aircraft ascent near 53°S latitude indicate no clear temporal trend in ozone mixing ratio but instead reflect the distance of the measurement from the chemically perturbed region. The measurements made within the ozone hole at 72°S show altitude dependent decreases in ozone of 61% at a potential temperature of 425 K down to 39% at 365 K. Temporal trends are also calculated at various positions relative to the boundary of the chemically perturbed region to locate the region of large ozone decreases and thereby accurately locate the boundary of the ozone hole.

AL-088

REID, G.C. Ice particles and electron "bite-outs" at the summer polar mesopause. Journal of Geophysical Research 94(D9):13,891-13,896 (1990).

Rocket measurements of electron density profiles in the vicinity of the high-latitude summer mesopause have frequently shown the existence of a sharply bounded layer of thickness ~ 1 km in which the electron density is depleted by as much as an order of magnitude below the value that would be inferred from the densities above and below. The most plausible explanation of these "bite-outs" is that they are caused by scavenging of the electrons by small ice particles that exist in the cold environment of the polar summer mesopause and that are related to those responsible for noctilucent and polar mesospheric clouds. This possibility is explored quantitatively using a simplified version of relations developed earlier (Natanson, 1960) to describe the charging of aerosols. It is shown that the radius of the ice particles must be of the order of 10 nm in order to satisfy the number density requirement and at the same time keep the water content within reasonable bounds. These particles would be too small to produce a visible cloud but may form a semipermanent substrate from which the larger cloud particles can develop under suitable conditions.

AL-089

REID, G.C. Ion chemistry of the cold summer mesopause region. Journal of Geophysical Research 94(D12):14,653-14,660 (1989).

Ions form important constituents of the cold summer mesopause region, since their tendency to form heavy clusters makes them a strong candidate for the nuleation cors of the ice particles that make up noctilucent and polar mesospheric clouds and since their chemical composition can yield important information about the thermal structure and the minor neutral composition of the mesopause region itself. The sources of mesospheric ionization at high latitudes and the outlines of the chemical reaction chains that determine the steady state positive ion composition are discussed. A one-dimensional model is used to calculate the steady state composition, and the main features are discussed, with emphasis on the altitude distribution of the proton hydrates and their dependence on such atmospheric variables as the temperature, the ionization rate, and the concentrations of water vapor and atomic oxygen. The model predictions are compared with mass spectrometer measurements made at high latitudes in summer, and the main descrepancies are pointed out. The possible role of negative ions is discussed briefly.

AL-090

REID, G.C., K.S. GAGE, and J.R. MCAFEE. The climatology of the western tropical pacific: Analysis of the radiosonde data base. Proceeding of Western Pacific International Meeting, Noumea, New Caledonia, 741-746 (1989).

No abstract.

AL-091

REID, G.C., K.S. GAGE, and J.R. MCAFEE. The thermal response of the tropical atmosphere to variations in equatorial pacific sea surface temperature. Journal of Geophysical Research 94(D12):14,705-14,716 (1989).

For the period 1966-1982, montnly mean temperature anomalies were determined for 30 pressure levels from 1000 mbar (0 km altitude) to 15 mbar (28 km) at five tropical radiosonde stations, four in the western Pacific Ocean (Yap, Majuro, Wake Island, and Pago Pago) and one in the Caribbean (Curacao). Long-term trends in the data were removed, and the detrended time series were cross correlated with an index of nonseasonal Pacific sea surface temperature (SST) anomalies with lags ranging up to ±30 months. At each station the correlation diagrams show a clear division of the atmosphere into four distinct regions, each having a different response to SST variations. In the main troposphere (850-150 mbar; 2-14 km) the correlation is positive, with a maximum at a lag of 10 months, in general agreement with earlier studies. In the lower stratosphere (100-40 mbar; 16-22 km) the correlation is negative, with a similar delay, while the surface layer (1000-850 mbar; 0-2 km) and the upper troposphere (150-100 mbar; 14-16 km) show responses that vary from station to station. The correlation drops essentially to zero above 40 mbar (22 km). Examination of the lags at the different stations indicate that the tropospheric in-phase and stratospheric out-of-phase responses appear to propagate zonally from an apparent point of origin in the east

central equatorial Pacific with a speed of the order of 1 m s^{-1}. The possible mechanisms underlying this propagation are discussed, and it is concluded that simple advection of air from centers of convective activity is unlikely to explain both the tropospheric and the stratospheric responses. An alternative explanation involving variations in the rate of tropospheric subsidence and stratospheric upwelling accompanying variations in convective activity is suggested. The long-term trends in atmospheric temperature are shown to have a variation with height that parallels the variation in the SST correlation. This may indicate that the atmosphere is responding to a corresponding long-term trend in Pacific sea surface temperatures.

AL-092

RIDDLE, A.C., K.S. GAGE, B.B. BALSLEY, W.L. ECKLUND, and D.A. CARTER. Poker flat MST radar data bases. NOAA Technical Memorandum ERL AL-11(1):37 (1989).

The Mesosphere, Stratosphere, Troposphere (MST) radar was operated by NOAA in Poker Flat, Alaska, from 1979 through 1985. The radar recorded all three wind velocity components (as well as turbulence measures) from approximately 5 to 30 km and 55 to 95 km. With data being recorded at intervals as short as 30 seconds, the data base represents a unique resource for a broad range of atmospheric studies. This document illustrates the range of data available, outlines the history of the radar and describes the data formats, from the raw data to the user friendly data base available at the National Center for Atmospheric Research, Boulder, CO, as part of the CEDAR data base.

AL-093

Ridley, B.A., J.D. Shetter, B.W. Gandrud, L.J. Salas, H.B. Singh, M.A. CARROLL, G. Hübler, D.L. ALBRITTON, D.R. Hastie, H.I. Schiff, G.I. MacKay, D.R. Karechi, D.D. Davis, J.D. Bradshaw, M.O. Rodgers, S.T. Sandholm, A.L. Torres, E.P. Condon, G.L. Gregory, and S.M. Beck. Ratios of peroxyacetyl nitrate to active nitrogen observed during aircraft flights over the eastern Pacific oceans and continental United States. Journal of Geophysical Research 95(D7):10,179-10,192 (1990).

During August and September 1986, 11 aircraft flights were made over the eastern Pacific Ocean and continental United States. The suite of observations included simultaneous measurements of peroxyacetyl nitrate (PAN) and active nitrogen ($NO_x = NO + NO_2$). At altitudes of 4.5-6.1 km in the middle free troposphere, PAN was usually 5-6 times NO_x in maritime air masses and 2-4 times NO_x in continental air masses. In air masses of tropical origin, or in the marine boundary layer, both PAN and NO_x were typically less than 20-30 parts per trillion by volume, and the PAN to NO_x ratio was less than one. The observations show that PAN can be a major component of the odd nitrogen budget in the middle free troposphere and strongly reinforce earlier views that the abundance is mainly governed by long-range transport processes including formation during transport and continental boundary layer to free tropospheric exchange of PAN and its precursors. Unlike reservoir HNO_3, PAN can be transformed to active nitrogen and peroxy radicals by a variety of physical atmospheric processes that lead to air mass warming. Since NO_x plays a critical role in determining photochemical O_3 production, which in turn determines the oxidative power of the atmosphere, the observed large ratios of reservoir PAN to active NO_x imply an important photochemical and dynamical role for PAN in the eastern Pacific remote free troposphere.

AL-094

Ridley, B.A., J.D. Shetter, J.G. Walega, S. Madronich, C.M. Elsworth, F.E. Grahek, F.C. FEHSENFELD, R.B. NORTON, D.D. PARRISH, G. Hübler, M. Buhr, E.J. Williams, E.J. Allwine, and H.H. Westberg. The behavior of some organic nitrates at Boulder and Niwot Ridge, Colorado. Journal of Geophysical Research 95:13,949-13,961 (1990).

Observations show that the ratio of peroxypropionyl nitrate (PPN) to peroxyacetyl nitrate (PAN) increases to a maximum in the afternoon period at Boulder and at Niwot Ridge. In Boulder air and in easterly flow reaching Niwot Ridge, maximum average PPN/PAN ratios were near 15%, while in westerly flow or more remote continental air, the ratio was much smaller and averaged 4%. Relative to the PAN-mixing ratios, methyl nitrate (MN) was less than 0.2% in the afternoon and less than 0.9% at night in Boulder air masses. The sum of ambient n-propyl nitrate (NPN) and 2-butyl nitrate (2BN) mixing ratios was also small, the diurnal average at Niwot Ridge being about 2% of the PAN-mixing ratio. The diurnal average contribution of MN + PPN + (NPN+2BN) to the total odd nitrogen budget at Niwot Ridge was at most 4%, leaving a 21-27% shortfall between the sum of individual measurements of odd nitrogen species and the total odd nitrogen (NO_y) measurement.

AL-095

Rodriguez, J.M., M.K.W. Ko, N.D. Sze, S.D. Pierce, J.G. Anderson, D.W. FAHEY, K. KELLY, C.B. Farmer, G.C. Toon, M.T. Coffey, L.E. Heidt, W.G. Mankin, K.R. Chan, W.L. Starr, J.F. Vedder, and M.P. McCormick. Nitrogen and chlorine species in the spring Antarctic stratosphere: comparison of models with airborne Antarctic ozone experiment observations. Journal of Geophysical Research 94(D14):16,683-16,703 (1989).

The Atmospheric and Environmental Research, Inc. photochemical model has been used to simulate the concentrations and time development of key trace gases in the Antarctic stratosphere before, during, and after the Airborne Antarctic Ozone Experiment (AAOE). The model includes complete gas phase photochemistry and heterogeneous reactions of $ClNO_3$ (g) and N_2O_5 (g) with HCl(s) and H_2O (s). Observations of long-lived species by the AAOE instruments have been used to constrain the initial conditions in our calculations. We

present results from four cases illustrating the evolution of the trace gases for a range of possible initial conditions and duration of heterogeneous activity. The amount of ClO produced by heterogeneous conversion of HCl is determined not only by the initial concentrations of NO_x ($NO + No_2 + NO_3$), N_2O_5, and $ClNO_3$ during winter, but also by the rate at which NO_x is resupplied by photolysis of N_2O_5 and HNO_3, or by transport. Results from the four cases presented bracket column measurements of HCl, $ClNO_3$, and HNO_3 by the Jet Propulsion Laboratory and National Center for Atmospheric Research infrared spectrometers onboard the NASA DC-8, and in situ measurements of ClO and NO_y by instruments aboard the NASA ER-2. Comparison of results and measurements of HCl and ClO suggests that heterogeneous chemistry was maintained throughout the month of September in 1987. We suggest field observations and kinetic data which would further constrain the photochemistry of the spring Antarctic Stratosphere. The behavior of ozone is discussed in a companion paper (Ko et al., this issue).

AL-096

Rosenfield, J.E., M.R. Schoeberl, L.R. Lait, P.A. Newman, M.H. Proffitt and K.K. KELLY. Radiative heating rates during the airborne Arctic stratospheric experiment. Geophysical Research Letters 17(4):345-348 (1990).

A radiative transfer model and observed temperature and ozone profiles are used to compute three dimensional fields of heating rates for the Northern Hemisphere during the 1989 Airborne Arctic Stratospheric Experiment. For a clear atmosphere, an average cooling of 0.2 to 0.4 K/day is computed in the regions of the ER-2 aircraft during flight days. Tropospheric clouds will increase the cooling by 0.1 to 0.2 K/day. These cooling rates are in good agreement with the diabatic cooling estimated from N_2O data. Net heating rather than cooling is computed in the area of ozone "minihole" which had its maximum on 1/31/89 in the vicinity of the mission. On 1/31/89 the 50 and 30 mb net heating rates are 0.1 to 0.2 K/day for clear skies, and 0.05 to 0.1 K/day for cloudy skies.

AL-097

Salawitch, R.J., M.B. McElroy, J.H. Yatteau, S.C. Wofsy, M.R. Schoeberl, L.R. Lait, P.A. Newman, K.R. Chan, M. Loewenstein, J.R. Podolske, S.E. Strahan, and M.H. Proffitt. Loss of ozone in the Arctic vortex for the winter of 1989. Geophysical Research Letters 17(4):561-564 (1990).

Measurements of ClO (Brune et al., 1990) acquired during the Airborne Arctic Stratospheric Expedition are used to infer concentrations of reactive chlorine ($ClO + 2xCl_2O_2$). Observed fields of potential temperature and potential vorticity are used to extrapolate *in situ* data to larger regions of the vortex. Calculated values of the loss rate of O_3, based on estimates of reactive chlorine and measurements of BrO (Toohey et al., 1990), suggest that the loss of O_3 was about 12% for levels of the atmosphere with potential temperatures between 440 and 470 K over the 39 day duration of the ER-2 flights into the polar vortex. Calculated loss rates agree with observed rates of removal of O_3, although significant uncertainties exist for each.

AL-098

Schoeberl, M.R., L.R. Lait, P.A. Newman, R.L. Martin, M.H. Proffitt, D.L. Hartmann, M. Loewenstein, J. Podolske, S.E. Strahan, J. Anderson, K.R. Chan, and B. Gary. Reconstruction of the constituent distribution and trends in the Antarctic polar vortex from ER-2 flight observations. Journal of Geophysical of Research 94(D14):16,815-16,845 (1989).

During the Airborne Antarctic ozone Experiment, the high-altitude ER-2 aircraft measured ozone, chlorine monoxide, and nitrous oxide concentrations in the south polar region. These measurements have been analyzed using conservative coordinate transformations to potential temperature-N_2O and potential temperature-potential vorticity space. The latter transformation is equivalent to interpreting trace species observations within the modified Lagrangian mean (MLM) coordinate system. With certain assumptions about zonal symmetry, this transformation allows for the interpretation of chemical changes of constituents independent of meteorological variability. The method also allows for a reasonable reconstruction of constituent distributions outside the aircraft flight track. Our analysis shows that the MLM transformed ozone concentration decreases at about 0.06 ppmv (parts per million by volume) per day between 20 and 16 km altitude inside the polar vortex during the mid-August to mid-September period. These ozone changes must be chemical in origin; they are also collocated with the region of high ClO. Outside the CPR (chemically perturbed region) at the highest aircraft altitudes, ozone systematically increases, suggesting a diabatic cooling of the order of 0.3-0.6 K/d. Within the CPR the cooling rate appears to be less than 0.2 K/d. The MLM analysis technique creates a picture of the general chemical structure of the Austral polar vortex which shows that air deep within the chemically perturbed region has subsided substantially in relation to the air outside. However, there is also a tongue of high ozone air which extends from mid-latitudes downward along the stratospheric jet at 65°W and 60°S. An examination of the last three flight days, September 20-22, 1987, shows that during this period the polar vortex shifts systematically equatorward along the Antarctic Peninsula. Apparent changes in the constituents measured over this period result from sampling air progressively further into the vortex.

AL-099

Schoeberl M.R., M.H. Proffitt, K.K. KELLY, L.R. Lait, P.A. Newman, J.E. Rosenfield, M. Loewenstein, J.R. Podolske, S.E. Strahan, and K.R. Chan. Stratospheric constituent trends from ER-2 profile data. Geophysical Research Letters 17(4):469-472 (1990).

Trend analysis of the AASE ER-2 profile data reveals an average decrease in N_2O on potential temperature isentropes which can be

attributed to diabatic cooling of inner vortex air. This conclusion is independently supported by radiative transfer computations. Trends in ozone and water vapor over the same period are not consistent with the magnitude of the diabatic descent. After accounting for the diabatic motion (estimated from N_2O) an additional 0.44±.3%/day average anomalous O_3 decrease above 440 *K* (~20 km) is needed to balance the continuity equation. This ozone decrease suggests additional photochemical destruction of ozone in the presence of the high amounts of ClO observed during the mission. A 0.4±0.3%/day average anomalous increase in H_2O is also observed near 420 *K* (~18 km) which may be due to the evaporation of ice crystals falling from higher, colder stratospheric layers.

AL-100

Singh, H.B., E. Condon, J. Vedder, D. O'Hara, B.A. Ridley, B.W. Gandrud, J.D. Shetter, L.J. Salas, B. Huebert, G. Hübler, M. A. CARROLL, D. L. ALBRITTON, D.D. Davis, J.D. Bradshaw, S.T. Sandholm, M.O. Rodgers, S.M. Beck, G.L. Gregory, and P.J. LeBel. Peroxyacetyl nitrate measurements during CITE 2: Atmospheric distribution and precursor relationships. Journal of Geophysical Research 95:10,163-10,178 (1990).

Aircraft measurements of peroxyacetyl nitrate (PAN) and other important reactive nitrogen species (NO, NO_2, HNO_3, and NO_y) were performed over the continental United States and the eastern Pacific during August-September 1986 at all altitudes between 0 and 6 km as part of CITE 2. PAN measurements were conducted by two independent groups, allowing both intercomparisons and greater confidence in its observed atmospheric structure. PAN was found to be a dominant reactive nitrogen species in the troposphere with 98% of the mixing ratios falling in a range of 5-400 ppt. Typically, the highest mixing ratios (100-300 ppt) were observed aloft (4-6 km) with extremely low values (5-20 ppt) in the marine boundary layer. In the lower troposphere, continental air contained significantly more PAN than marine air. The vertical structure of PAN was largely dictated by its thermal destruction rate and equilibrium with available NO_2. PAN mixing ratios showed a high degree of variability in both continental and marine atmospheres. Westerly marine air trajectories did not guarantee well-mixed air of uniform composition. Mixing ratios of O_3, NO_y, NO_x, HNO_3, C_2H_6, CO, and $CFCl_3$ were strongly correlated with those of PAN, indicating the important role played by transport processes. High PAN to NO_x ratios in the mid-troposphere further support the importance of long-range transport from continental sources. Frequently, descending air masses from the upper troposphere suggested that PAN mixing ratios probably continued to increase above the 6-km ceiling altitude. Air masses with O_3 <20 ppb, CO < 60 ppb, and C_2H_6 <500 ppt contained only minuscule amounts of PAN and are expected to be of tropical origin. Reasons for the observed PAN variability are discussed.

AL-101

Smith, J.P., and S. SOLOMON. Atmospheric NO_3 3. Sunrise disappearance and the stratospheric profile. Journal of Geophysical Research 95(D9):13,819-13,827 (1990).

New ground-based measurements of NO_3 absorption in the band near 662 nm were carried out using the moon as a light source during sunrise on July 1, 1988. As the sun rose, the observed slant column abundance of atmospheric NO_3 decreased systematically. This time-dependent decrease is expected, due to the progression of the solar terminator down through the atmosphere, and provides a basis for inferring the nighttime vertical profile of NO_3. This approach represents a new means of measuring the vertical profile of stratospheric species whose distributions change rapidly at sunrise. The profile inferred from the time-dependent NO_3 decrease is sensitive to the NO_3 absorption cross section and the adopted photolysis rate, and these sensitivities are investigated. The inferred vertical profile on July 1, 1988, is in excellent agreement with theoretical predictions in the altitude range from about 20 to 33 km. At higher levels near 40 km, the NO_3 abundance is found to be quite sensitive to the adopted rate constant for thermal decomposition of N_2O_5. The profile inferred from these measurements suggests a relatively slow rate of N_2O_5 thermal decomposition in this region.

AL-102

SOLOMON, S. Progress towards a quantitative understanding of Antarctic ozone depletion. Nature 347(6291):347-354 (1990).

The possibility that the stratospheric ozone layer could be depleted by half at certain latitudes and seasons would have been deemed a preposterous and alarmist suggestion in the early 1980s. A decade later, the statement is acknowledged as proved beyond reasonable scientific doubt. Observations of the composition of the Antarctic stratosphere have established that the chemistry of this region is highly unusual because of its extreme cold temperatures, leading to a greatly enhanced susceptibility to chlorine-catalysed ozone depletion.

AL-103

SOLOMON, S., R.W. SANDERS, and H.L. Miller, Jr. Visible and near-ultraviolet spectroscopy at McMurdo Station, Antarctica 7. OC1O diurnal photochemistry and implications for ozone destruction. Journal of Geophysical Research 94(D9):13,807-13,817 (1990).

Observations of the ratio between the change in slant column abundance of OC1O and that of ozone as a function of solar zenith are used to deduce the diurnal cycle of the daytime OC1O column abundance above Antarctica during September 1987. This approach effectively normalizes other factors such as air mass factor changes and allows study of the photochemical variations of OC1O during

twilight. The data exhibits a marked increase in OC1O at large solar zenith angles in the evening twilight (near 90°-93°), in agreement with model predictions. the increase is likely caused primarily by the attenuation of the OC1O photolysis rate in the twilight. Knowledge of both the full diurnal and daily variations of OC1O deduced from the data can be used to evaluate the destruction of the ozone column due to coupled chlorine-bromine chemistry. The inferred ozone loss above McMurdo Station assuming presently accepted photochemistry is 19.5±10 Dobson units over the entire month of September, or about 20±10% of the observed total column decline. This value is in general agreement with inferences drawn from in-situ mesurements of C1O and BrO. In mid-September, available OC1O and HOC1 column measurements suggest that the chlorine-bromine and chlorine-hydrogen cycles respectively contribute about 22-28% and 3-4% of the observed rate of column ozone decrease at that time of the month. Model calculations constrained by C1O, BrO, and OC1O measurements suggest that these mechanisms combined with photolysis of the C1O dimer can account for much, and possibly all, of the total ozone destruction rate observed in mid-September 1987.

AL-104

SOLOMON, S., R.W. SANDERS, G.H. MOUNT, M.A. CARROLL, R.O. JAKOUBEK, and A.L. SCHMELTEKOPF. Atmospheric NO_3 2. Observations in polar regions. Journal of Geophysical Research 94(D13):16,423-16,427 (1989).

Stratospheric NO_3 is expected to depend strongly upon two major factors: solar illumination and temperature. This paper presents observations in the polar regions that confirm the influence of both of these on the NO_3 column abundance. Measurements of the absorption of incoming lunar radiation near 662 nm as the sun rises exhibit large changes that apparently reflect the rapid photolysis of NO_3. The increase in upper stratospheric temperature that occurs in early spring in polar regions should also affect the seasonal changes in stratospheric NO_3 abundances. Observations of stratospheric NO_3 at 76.5°N in early February are contrasted with those obtained at 77.8°S in late August and September. Large seasonal differences in stratospheric temperatures between these two locations and times are shown to be in excellent agreement with the observed NO_3 column amounts, providing further support for current understanding of the factors controlling the stratospheric NO_3 abundance and its variability. The findings provide further evidence against a stratospheric "scavenger" for NO_3, even in polar latitudes, where the scavenging effect was believed to be most pronounced.

AL-105

SOLOMON, S., and A.L. SCHMELTEKOPF. Visible and near-ultraviolet spectroscopy at McMurdo Station, Antarctica 6. Observations of BrO. Journal of Geophysical Research 94(D14):16,633-16,638 (1989).

Observations of the evening twilight BrO abundance over McMurdo Station, Antarctica during austral spring, 1987, are described. The observed variation of the slant column abundance with increasing solar zenith angles suggest that most of the BrO is located near 15 km. The total vertical column abundance observed during 1 week of measurements yielded an average value of 2.5×10^{13} cm^{-2}, assuming the room temperature absorption cross sections measured by Cox et al. (1982). These values are consistent with BrO mixing ratios of about 5-15 parts per trillion by volume distributed from 150 to 20 mbar. If the differential absorption cross section of BrO increases by 30% at temperatures characteristic of the Antarctic lower stratosphere, as indicated by Saner and Watson (1981), then the BrO measurements reported in this paper should be decreased by 30%.

AL-106

Strahan, S.E., M. Loewenstein, J.R. Podolske, W.L. Starr, K.R. Chan, M.H. Proffitt, and K.K. KELLY. Correlation of N_2O and ozone in the southern polar vortex during the airborne Antarctic ozone experiment. Journal of Geophysical Research 94(D14):16,749-16,756 (1989).

N_2O mixing rations, measured in situ by an airborne laser spectrometer (ATLAS), have been used along with in situ ozone measurements to determine the correlation of N_2O and ozone in the Antarctic stratosphere during the late austral winter. N_2O and ozone measurements on five transit flights between Ames Research Center, California (37°N), and Punta Arenas, Chile (53°S), were used to determine the correlation of N_2O and ozone between 13 and 20 km in the mid-latitudes. The mid-latitude correlation is negative ≤ -0.5). However, poleward of 53°S, N_2O and ozone often show a strong positive correlation which approximately coincides with the wind speed maximum surrounding the Antarctic vortex. Strong zonal winds appearing between 60° and 70°S are colocated with strong potential vorticity gradients, indicating that the wind speed maximum is a good marker for the vortex boundary. Flight tracks penetrating well beyond the wind maximum show a return to negative correlation. With few exceptions, regions in the vortex with positive N_2O and O_3 correlation are colocated with total water mixing ratios of greater than 2.9 ppmv, and negatively correlated regions with water mixing ratios of less than 2.9 ppmv. The driest regions appear to be colocated with the greatest ozone loss. Because positive correlation between N_2O and O_3 cannot be explained by horizontal or vertical transport (below 35 km), N_2O/O_3 correlations appear to be a sensitive indicator of chemical loss of ozone.

AL-107

Trolier, M., R.L. Mauldin III, and A.R. RAVISHANKARA. The rate coefficient for the thermolecular channel of the self-reaction of ClO. Journal of Physical Chemistry 94: 4896-4907 (1990).

The rate coefficient for the reaction ClO + ClO $\xrightarrow{M}$ Cl_2O_2 has been measured by using a flash photolysis/UV absorption technique at temperatures from 200 to 263 K and pressures from 25 to 600 Torr in N_2, O_2, He, and SF_6. Conventional single-wavelength detection and diode array spectrometry have both been employed in monitoring the reactant and product species. The UV absorption cross section of ClO has been measured in the same temperature range, from 220 to 350 nm, by using the diode array, and at 282.65 nm (the maximum of the ClO (9,0) band) by using the single-wavelength detection. The reactions of chlorine atoms with O_3 and Cl_2O have been used to produce ClO. The title reaction is believed to play a role in the loss of ozone from the Antarctic stratosphere during the austral spring. At the temperatures and pressures relevant to the Antarctic stratosphere, our measured values agree with the recent work of Sander et al. and are considerably smaller than the values obtained by Hayman et al. Over the range of conditions relevant to the Antarctic ozone loss, our measurements differ from Hayman et al. by a factor ranging from 1.3 to 3.0, with the discrepancy being ~ 1.9 at the altitude of maximum ozone loss. We have found Cl_2O_2 to be the major product of this reaction under these conditions, and we have established an upper limit of 1% for the production OClO.

AL-108

Tsuda, T.S., S. Kato, T. Yokoi, T. Inoue, M. Yamamoto, T.E. VANZANDT, S.Fukao, and T. Sato. Gravity waves in the mesosphere observed with the MU radar. Radio Science 25(5):1005-1018 (1990).

We have observed wind motions from 60 to 90 km altitudes with the middle and upper atmosphere (MU) radar during daylight hours (0800-1600 LT) from October 13 to 31, 1986. Gravity waves with fairly sinusoidal vertical structure were evident on 16 days of the 19 days of observations. They were characterized by a typical vertical wavelength of 5-15 km and intrinsic periods centered at about 8.6 hours. The propagation velocity of these waves was determined using the linear gravity wave theory. All of the waves propagated downward and had an equatorward component of the meridional propagation. The median direction of horizontal propagation was slightly east of south, and the mean horizontal phase speed was 35.3 m/s. The vertical wave number spectra of horizontal components of mesoscale wind fluctuations agree well with the theoretical spectrum of saturated gravity waves. At frequencies from 1 x 10^{-5} c/s frequency spectra of vertical and radial wind components had logarithmic slopes of 1/3 and -5/3, respectively, which agree fairly well with a model gravity wave spectrum. The effects of Doppler shifting on frequency spectra are most obviously recognized at large frequencies near the Brunt Väisälä frequency. We have also determined the upward flux of horizontal momentum induced by waves with periods from 10 min to 8 hours and further estimated the westward and northward body force of 5.1 and 4.0 m/s/d, respectively.

AL-109

Tyndall, G.S., and A.R. RAVISHANKARA. Atmospheric reactions of CH_3S radicals. In Biogenic Sulfur in the Environment, E.S. Saltzman, and W.J. Cooper (eds.). ACS Symposium Series 393. American Chemical Society, Washington, DC, 450-458 (1989).

Rate coefficients have been measured for the reactions of CH_3S radicals with NO_2 and O_2 at 298 K. The rate coefficient for $CH_3S + NO_2$ is (6.1 ± 0.7) x 10^{-11} cm^3 $molec^{-1}$ s^{-1}. NO was found to be the major product of the reaction, consistent with the mechanism $CH_3S + NO_2 \rightarrow CH_3SO + NO$. CH_3SO reacts with NO_2 to give $CH_3SO_2 + NO$. We were only able to assign an upper limit, ≤ 2.5 x 10^{-18} cm^3 $molec^{-1}$ s^{-1}, to the rate coefficient for the reaction of CH_3S with O_2. Despite this low rate coefficient this reaction could still be important in the marine troposphere. The impact of these rate coefficients on the production of SO_2 and CH_3SO_3H in the atmosphere is discussed.

AL-110

Vaghjiani, G.L., and A.R. RAVISHANKARA. Photodissociation of H_2O_2 and CH_3OOH at 248 nm and 298K: Quantum yields for OH, $O(^3P)$ and $H(^2S)$. Journal of Chemical Physics 92:996-1003 (1990).

The quantum yields of the products, $OH(X^2\Pi)$, $O(^3P)$ [plus $O(^1D)$] and $H(^2S)$, in the photolysis of H_2O_2 and CH_3OOH at 248 nm and 298 K have been measured. OH was directly observed by laser-induced fluorescence while the atomic species were detected by cw-resonance fluorescence. All quantum yield measurements were made using relative methods. The quantum yields of OH, O, and H in H_2O_2 photolysis were measured relative to the well known quantum yields of $O(^1D)$ and $O(^3P)$ in the photodissociation of O_3, and $H(^2S)$ in CH_3SH. The values we obtain are, 2.09 ± 0.36, <0.002 and <0.0002 for OH, O, and H, respectively. For CH_3OOH photolysis, the quantum yield of OH was measured relative to our value for OH quantum yield in H_2O_2 photolysis, and the quantum yields of O and H relative to those in O_3 and CH_3SH photodissociation, respectively. In both H_2O_2 and CH_3OOH photolysis, the observed O and H quantum yields showed an apparent dependence on the fluence of the photolysis light, the possible origin of which is discussed. The large quantum yield of OH we measure is consistent with the known continuous and unstructured absorption spectra of these molecules in this wavelength region, where the most important process is the dissociative ($A^1A \leftarrow X^1A$) transition to give $OH(X^2\Pi, v'' = 0)$ fragment.

AL-111

Vaghjiani, G.L., and A.R. RAVISHANKARA. The rate coefficient for the reaction of $O(^3P)$ with CH_3OOH at 297 K. International Journal of Chemical Kinetics 22:351-358 (1990).

The absolute second-order rate coefficient for the reaction, $O(^3P) + CH_3OOH \rightarrow$ products, was measured to be $k_1 = (1.06 \pm 0.26) \times 10^{-14}$ cm^3 $molec^{-1}$ s^{-1} at 297 K, where the quoted error is 2σ including precision and estimated systematic errors. The possible presence of $(CH_3CH_2)_2O$ in our sample of CH_3OOH leads to a large error in k_1 which reflects the relatively large uncertainty indicated. $O(^3P)$ was generated in excess CH_3OOH by photolyzing a small amount of O_3 at 532 nm, where CH_3OOH does not photolyze. The rate of removal of $O(^3P)$ in the experiments was monitored by resonance fluorescence detection. The increased reactivity of $O(^3P)$ with CH_3OOH relative to H_2O_2 is interpreted as due to H abstraction from the CH_3 group.

AL-112

Vaghjiani, G.L., A.R. RAVISHANKARA, and N. Cohen. Reactions of OH and OD with H_2O_2 and D_2O_2. Journal of Physical Chemistry 93:7833-7837 (1989).

The reaction $OH + H_2O_2 \rightarrow$ products (k_1) and $OD + D_2O_2 \rightarrow$ products (k_3) were studied in the temperature range 273-410 K. The obtained Arrhenius expressions are as follows: $k_1 = (2.76 \pm 0.80) \times 10^{-12} \exp((-110 \pm 60)/T)$ and $k_3 = (1.75 \pm 0.30) \times 10^{-12} \exp((-320 \pm 20)/T)$ cm^3 $molecule^{-1}$ s^{-1}. The indicated errors are 2σ, including estimated systematic errors. The rate coefficients were independent of the buffer gas (He, N_2, or SF_6) used and the pressure (50-500 Torr) employed The measured kinetic isotope effect, k_1/k_3, ranges from 2.7 at 410 K to 3.5 at 273 K. The values of the rate coefficients for $OH + D_2O_2 \rightarrow$ products (k_2) at 273 K and $OD + H_2O_2 \rightarrow$ products (k_4) at 298 K were the same as those of k_3 at 273 K and k_1 at 298 K, respectively. The possible exchange reaction such as $OD + H_2O_2 \rightarrow OH + HOOD$ is unimportant, with an upper limit of 2×10^{-15} cm^3 $molecule^{-1}$ s^{-1} for the rate coefficient at 273 K. Bond energy-bond order (BEBO) calculations using a linear five-particle transition state for a H-abstraction reaction do not yield results that agree with experiments. Transition-state theory calculations using a five-particle nonlinear transition state, (HO)-O-H-O-H, yield results in reasonable agreement with the data.

AL-113

Vaida, V., S. SOLOMON, E.C. Richard, E. Ruhl, and A. Jefferson. Photoisomerization of OC1O: A possible mechanism for polar ozone depletion. Nature 342(23):405-408 (1989).

No abstract.

AL-114

VANZANDT, T.E., S.A. Smith, T. Tsuda, D.C. Fritts, T. Sato, S. Fukao, and S. Kato. Studies of velocity fluctuations in the lower atmosphere using the MU radar. I: Azimuthal Anisotropy. Journal of Atmospheric Sciences 47:39-50 (1990).

We present in this paper a study of the azimuthal anisotropy of the motion field observed during a six-day campaign in March 1986 using the MU radar in Shigaraki, Japan. The radial wind velocity was observed at 20° zenith angle, at every 30° of azimuth during four days, and at every 45° during two days. A jet stream was present during the entire six days. The average radial velocity variance from 10.4 to 19.2 km was calculated every four minutes and then averaged over 20 minutes or one hour. The average variance was found to be a strong function of both azimuth and time. The azimuthal variations were analyzed in terms of the mean and the first and second harmonics. The mean is proportional to the kinetic energy per unit mass of the radial wind fluctuations, and the first harmonic is proportional to the vertical flux of horizontal momentum per unit mass. The strong azimuthal variation was usually dominated by the second harmonic; ie., with two peaks, but was occasionally dominated by the first harmonic, with one peak. The phase of the first harmonic was usually westward, but the phase of the second harmonic was quite variable. It was shown by a development of gravity wave theory that all of the observed azimuthal variations could probably be caused by a gravity wave field whose parameters vary with time.

AL-115

Wahner, A., R.O. JAKOUBEK, G.H. MOUNT, A.R. RAVISHANKARA, and A.L. SCHMELTEKOPF. Remote sensing observations of daytime column NO_2 during the airborne Antarctic ozone experiment: 22 August - 2 October 1987. Journal of Geophysical Research 94:16,619-16,632 (1989).

A sensitive absorption spectrograph was flown on the NASA DC-8 aircraft as part of the 1987 Airborne Antarctic Ozone Experiment to measure column abundances of O_3, NO_2, OC1O, and BrO inside the Antarctic polar vortex. The instrument functioned successfully on all flights. Slant column NO_2 measurements were made every 300 s whenever light levels permitted observation with an absolute accuracy better than 20% and with a detection limit of 3.4×10^{15} cm^{-2} slant column These measurements are presented and compared with TOMS total ozone along the flight track.

AL-116

Watterson, I.G., and A.F. TUCK. A Comparison of the longitudinal distributions of polar stratospheric clouds and temperatures for the 1987 Antarctic spring. Journal of Geophysical Research 94(D14):16,511-16,525 (1989).

The Stratospheric Aerosol Measurement (SAM) II stratospheric extinction coefficients have been analyzed to provide information on the geographical distribution of Antarctic stratospheric clouds in 1987. The peak extinction above 15 km was determined for each of the approximately 14 vertical profiles each day. A longitude by time graph of this extinction is presented, extending from early June to late October. Similar graphs for extinction at 17 km and for temperature at 17 km and 70 mbar geopotential height from the National Meteorological Center at the measurement locations are also shown. It is assumed that extinction is a measure of cloud density. Statistics of the fractional incidence of cloud and of temperature and pressure for five time periods and 24 longitudinal sectors are presented. Cloud incidences for latitudes which either cross or pass to the south of the Antarctic Peninsula are shown. In order to remove the effect of the latitudinal drift of the measurements the statistics are also shown for data binned by 70-mbar geopotential height relative to the minimum within the vortex. In general, there is a good correlation between enhanced extinctions and cold temperatures. Both exhibit a planetary wave structure which tends to move eastward. However, the distribution of dense clouds is highly zonally asymmetric and unlike that of temperature. These clouds are very rare over East Antarctica even when temperatures are low there. After July, clouds are also rare close to the center of the vortex, as determined by the 70-mbar geopotential height of the measurement locations. It is concluded that both cold temperature and the availability of condensable material are important in determining the location of cloud. The dehydration of the interior of the vortex through sedimentation restricts cloud formation as early as July 3. Cloud formation is closely associated with tropospheric weather systems which produce colder temperatures in the lower stratosphere through adiabatic expansion in the poleward flow to the east of the cyclonic region. In addition, moister air from farther out in the vortex can pass across the measurement locations because of the poleward flow. In August and September, clouds were periodically detected by SAM II in the 90° to 0°W sector between 75° and 78°S, well to the south of the northern edge of the chemically perturbed region of the ozone hole. The clouds occurred at temperatures and relative 70 mbar heights similar to those of locations over East Antarctica where low extinctions were usually measured. The difference in fractional incidence of cloud between the regions suggests that some resupply of condensable material by irreversible mixing occurred in the 90° to 0°W sector, to an altitude of at least 17 km and a potential temperature of at least 410 K.

AL-117

WEINSTOCK, J. Saturated and unsaturated spectra of gravity waves, and scale dependent diffusion. Journal of Atmospheric Science 47:2,210-2,225 (1990).

For a highly idealized condition, the spectrum of saturated and unsaturated gravity waves at each height is calculated directly from the wave equation. A principal feature of this wave equation is the inclusion of wave dissipation, although in an approximate form. In the absence of wave absorption, reflection, radiation, wind shears, resonant wave-wave interactions and other sources and sinks, this dissipation at each height is determined solely by the "turbulent" or chaotic state induced by the (broad) wave spectrum at that height. The dissipation is then assumed to be approximately accounted for by a diffusion term. The appropriate diffusivity is self=consistent with the continuum of spectral waves that cause the chaotic state and is argued to be scale dependent. An inverse calculation is also made of what the observed spectra imply for wave dissipation - again assuming that many wave dissipations can be approximately described by a scale-dependent diffusion process. The relationship of middle atmospheric spectra to (averaged) gravity wave sources in the troposphere is investigated.

AL-118

Wilson, J.C., M. Loewenstein, D.W. FAHEY, B. Gary, S.D. Smith, K.K. KELLY, G.V. Ferry, and K.R. Chan. Observations of condensation nuclei in the airborne Antarctic ozone experiment: implications for new particle formation and polar stratospheric cloud formation. Journal of Geophysical Research 94(D14):16,437-16,448 (1989).

The ER-2 Condensation Nucleus counter (ER-2 CNC) was operated in the Airborne Antarctic Ozone Experiment in August, September, and October 1987. The ER-2 CNC measures the mixing ratio of particles, CN, with diameters from approximately 0.02 μm to approximately 1 μm. Comparisons of CN and other aerosol measurements with N_2O show that the vertical profile of the sulfate aerosol was probably displaced downward by the subsidence and mixing processes that determined the inclination of the N_2O isopleths. At altitudes above the minimum in the CN mixing ratio profile, CN mixing ratios correlated negatively with that of N_2O, demonstrating new particle production. The region of particle production was above and south of the 160 ppbv N_2O isopleth. The relationship between CN and N_2O did not change noticeably when moving from air containing normal levels of reactive nitrogen compounds (NO_y) to air depleted in those compounds. This suggests that the removal of NO_y was accompanied by the removal of a small minority of the CN. Concentrations of CN are compared with those of larger particles to study cloud formation mechanisms. In come cases condensation of water or nitric acid trihydrate following rapid cooling caused most of the CN to grow to diameters larger than 0.81 μm. Models published elsewhere predict that these conditions should result in a large fraction of particles growing to these sizes. Episodes of this type probably did not remove reactive nitrogen compounds through particle sedimentation from the chemically perturbed region. Small numbers of large particles were observed in other instances. The composition of the particles and their origins are unclear.

AL-119

Yatteau, J.H., S.C. Wofsy, R.J. Salawitch, M.B. McElroy, M.R. Schoeberl, L.R. Lait, P.A. Newman, A. Torres, T. Jorgensen, W.G. Mankin, M.T. Coffey, G.C. Toon, M. Loewenstein, J.R. Podolske, S.E. Strahan, K.R. Chan, and M.H. Proffitt. Effects of atmospheric transport on column abundances of nitrogen and chlorine compounds in the Arctic stratosphere. Geophysical Research Letters 17(4):533-536 (1990).

In the absence of heterogeneous processes, distributions of NO_y, HNO_3, Cl_x and HCl in the polar winter stratosphere should be determined by transport. A model simulating distributions of these species in the arctic for January and February 1989 is developed using observed fields of potential vorticity and potential temperature. Comparison of model results with column measurements from the DC-8 indicates conversion of NO_x to HNO_3, condensation of HNO_3, conversion of HCl to $ClNO_3$, and conversion of HCl plus $ClNO_3$ to an unmeasured species. Heterogeneous processes strongly affect abundances of NO_y and Cl_x species in the winter Arctic stratosphere.

AIR RESOURCES LABORATORY

AR-001

Addis, R.P., S.S. Bunker, R.J. Dobosy, R. Lange, and W.M. Porch. Model Evaluation Studies (U). Contract Report No. DE-AC09-88SR18035, U.S. Department of Energy, 1989. Preprints, 2nd International Workshop on Real-Time Computing of the Environmental Consequences of an Accidental Release to the Atmosphere from a Nuclear Installation, Luxembourg, May 15-19, 1989. Commission of European Communities, Brussels (1990).

The Office of Health and Environmental Research (OHER) of the U.S. Department of Energy (DOE) sponsors an ongoing series of atmospheric field studies whose main objectives are to increase fundamental knowledge of atmospheric transport and dispersion. This knowledge is used to develop technologies and methodologies required for both air quality assessments and real-time emergency response. The level of activity surrounding these field exercises has been sufficient and sustained over recent years to enable the development of measurement and modeling skills as well as the development of a wide variety of data bases useful for model evaluation. This has provided a unique opportunity for atmospheric modelers and experimentalists alike to participate in the design of these experiments to understand better the atmospheric processes involved and to determine what measurements are required by the models. These field studies have ranged from point releases of tracers in relatively simple terrain, to intensive field studies in extremely complex terrain. Scales have ranged from the mesoscale to the synoptic. This paper will give an overview of several DOE/OHER sponsored field experiments with particular emphasis on the role they have played in helping to improve and evaluate real-time atmospheric transport and dispersion models. The Mesoscale Atmospheric Transport Studies (MATS) and STable Atmospheric Boundary Layer Experiment (STABLE), conducted at Savannah River Site in South Carolina, have provided valuable data for model evaluation over gently rolling forested terrain. In contrast, the extensive series of Atmospheric Studies in COmplex Terrain (ASCOT) involve experiments in the extremely complex terrain of the Geysers area of northern California and Brush Creek in Colorado. Remote sensing has played a significant role in ASCOT in providing meteorological parameters for input into models. The vital role played by models in the initial design of these experiments will also be discussed.

AR-002

ANGELL, J.K. Influence of equatorial QBO and SST on polar total ozone, and the 1990 Antarctic ozone hole. Geophysical Research Letters 17(10):1569-1572 (1990).

Based on data through 1989, comparisons are made between the variation of total ozone at Resolute, Canada (75°N) and South Pole, and the variation of low-stratospheric temperature at Singapore (reflecting the equatorial QBO) and SST in eastern equatorial Pacific (reflecting the ENSO phenomenon). Total-ozone variations at Resolute have been more closely related to the QBO, whereas the total-ozone variations at South Pole appear to have been almost equally related to QBO and SST. When the average of 50 mb and 30 mb June-July-August (JJA) values of Singapore temperature ($\bar{T}$) increased from one year to the next, the decrease in South Pole springtime total ozone for the same years averaged 21 $\pm$ 14% greater than when $\bar{T}$ decreased. When the JJA values of equatorial SST increased from one year to the next, the decrease in South Pole springtime total ozone for the same years averaged 18 $\pm$ 12% greater than when SST decreased. In the 6 cases when JJA values of both Singapore $\bar{T}$ and equatorial SST increased from one year to the next, the spring values of South Pole total ozone have decreased, whereas in the 6 cases when both $\bar{T}$ and SST decreased from one year to the next, South Pole total ozone has increased. Both Singapore $\bar{T}$ and equatorial SST will probably be warmer in JJA of 1990 than they were in JJA of 1989 suggesting, based on these previous relations, an even deeper Antarctic ozone hole in 1990 than in 1989 and ending the biennial variation in depth of the hole of the last 6 years.

AR-003

ANGELL, J.K. On the relation between atmospheric ozone and sunspot number. Journal of Climate 2(11):1404-1416 (1989).

Based on data from the Dobson network, between 1960 and 1987 there has been a zero-lag correlation of 0.48 between the 112 unsmoothed seasonal values of sunspot number and global total ozone, significant at the 1% level taking into account the considerable serial correlation in these data. The maximum correlation of 0.54 is found when sunspot number lags total ozone by 2 seasons, the result mainly of a phase difference early in the record. On the basis of only 2 1/2 solar cycles, the global total ozone has increased by 1.4% for an increase in sunspot number of 100. The correlation between sunspot number and total zone has been significant at the 5% level in north temperate and tropical zones, the zones with the most representative data. In the north temperate zone the correlation between sunspot number and total ozone has been much higher in the west-wind phase of the 50 mb equatorial QBO than in the east-wind phase, but in the tropics the correlation has been much higher in the east-wind phase. Umkehr measurements between 1966 and 1987 in the north temperate zone indicate that the correlation between sunspot number and ozone amount has been higher (0.35, almost significant at the 5% level) in the low stratosphere where transport processes dominate than in the high stratosphere where photochemical processes dominate. During 1932-60 there was a significant correlation of 0.35 between sunspot number and Arosa total ozone 14 seasons later, very different from the nearly in-phase relation found after 1960. Considered is the possible impact of long-term change in transport processes in the low

stratosphere on the total-ozone record at a single station such as Arosa. Between 1966 and 1985 there has been very good agreement between observed global total ozone, and global total ozone calculated from three 2-dimensional stratospheric models which take into account the solar cycle, the time variation in trace gases and nuclear tests, both observed and calculated variations closely related to the variation in sunspot number. Between 1960 and 1966, however, the agreement between observation and calculation is poor, the models indicating a pronounced minimum in global total ozone in 1963 due to the nuclear tests of the early 1960's, a minimum not found in this analysis. The observed variation in global total ozone has been compared with the variation predicted by one of the models up to the sunspot maximum in 1990, and the agreement is shown to be good through the northern summer of 1988 if the impact of the QBO on global total ozone is taken into account. On the basis of the present analysis, there has been a 1.0 $\pm$ 0.9% decrease in global total ozone between solar cycles 20 and 21, a decrease 70% larger than that indicated by the three stratospheric models.

AR-004

ANGELL, J.K. Variation in global tropospheric temperature after adjustment for the El Nino influence, 1958-89. Geophysical Research Letters 17(8):1093-1096 (1990).

Data from a 63-station radiosonde network are used to estimate the variation in global tropospheric (850-300 mb) temperature between 1958 and 1989. The annual temperature was a maximum in 1988, 0.42°C above the 1958-88 mean. However, the value is indicated to be only 0.12°C above this mean. During 1958-88, there has been a correlation of 0.76 (significant at the 0.1% level) between annual values of global tropospheric-temperature deviation and annual values of sea-surface temperature (SST) deviation in eastern equatorial Pacific two seasons earlier. The associated linear-regression line indicates that an annual SST deviation of 1°C in the region 12°S-2°N, 180°-90°W has been related on average to an annual global tropospheric-temperature deviation of 0.36°C. The annual values of global tropospheric temperature have been adjusted based on this regression. With this adjustment, the year-to-year variability in global tropospheric temperature is halved, the increase in decadal-mean temperature between the 1960's and 1980's is reduced from 0.33°C to 0.24°C, the annual temperature is a maximum in 1989 (0.39°C above the 31-year mean) rather than in 1988, and there is much more convincing evidence that the eruptions of Agung in 1963 and El Chichon in 1982 decreased global tropospheric temperatures by 0.2-0.3°C for about 3 years.

AR-005

ANGELL, J.K. Variation in United States cloudiness and sunshine duration between 1950 and the drought year of 1988. Journal of Climate 3:296-308 (1990).

The variations in United States cloudiness (percent of sky covered by clouds, as estimated subjectively by observers at 100 National Weather Service stations) and sunshine duration (percent of possible sunshine, as estimated objectively by sunshine recorders at these same 100 stations) are examined for years 1950-88. During this period, the correlation between annual values of cloudiness and sunshine duration within the contiguous United States was -0.86 significant at the 1% level. The years of maximum cloudiness, and minimum sunshine duration, were 1972 and 1982 when strong El Ninos began. The year of maximum sunshine duration was 1988, but the years of minimum cloudiness were 1952-56 (mini dust bowl), the discrepancy a result of the greater long-term increase in cloudiness than decrease in sunshine duration. In the spring of 1988 there were anomalous values of cloudiness (below average) and sunshine duration (above average) in North Central, South Central and Southeast regions of the United States, the deviations from average approaching 10%. In the summer of 1988 these deviations were anomalous only in North Central and Northwest regions. Despite the low cloudiness in 1988, based on this analysis the United States cloudiness increased by 2.0 $\pm$ 1.3% between 1950-68 and 1970-88 (corresponding to a percentage increase of 3.5% since the average cloudiness was 58%, or 5.8 tenths, during 1950-88). The increase in cloudiness was close to 2% in all 6 regions of the country, and significant at the 5% level in all regions except the Southeast. Most of the increase in cloudiness was in autumn, with a negligible increase in spring. The decrease in United States sunshine duration between 1950-68 and 1970-88 is indicated to be only -0.8 $\pm$ 1.2%, however (corresponding to a percentage decrease of -1.2% since the average sunshine duration was 63% during 1950-88). The difference between cloudiness increase, and sunshine-duration decrease, is most apparent in the West and may be due in part to an increase in cirrus not thick enough to turn off the sunshine recorder. There has been a correlation of 0.79 (significant at the 1% level) between annual cloudiness and precipitation within the United States during 1950-88, but the correlation of -0.43 between annual cloudiness and surface temperature (above-average cloudiness associated with below-average temperature) is not quite significant at the 5% level. Considered is the possible relation between the 1987 El Nino and United States cloudiness and sunshine duration.

AR-006

ARTZ, R.S. Global monitoring at the United States baseline stations with emphasis on precipitation chemistry measurements. Environmental Monitoring and Assessment 12:255-267 (1989).

The National Oceanic and Atmospheric Administration Geophysical Monitoring for Climatic Change program has operated four remote precipitation chemistry stations at two polar and two tropical Pacific locations for over a decade. Station geography and meteorology is discussed and a summary of the hydrogen, sulfate, and nitrate ion data collected since 1980 is presented. Results show that at all four locations, the ions which have major anthropogenic sources were far less concentrated than in samples collected in heavily industrialized

areas in the northeastern United States and Europe. Concentrations at American Samoa and the South Pole showed little variability over the year whereas concentrations at Point Barrow, Alaska and Mauna Loa, Hawaii were highly variable.

AR-007

BALDOCCHI, D.D. Book Review. Climate Shocks: Natural and Anthropogenic. (K. Ya. Kondratyev, J. Wiley & Sons, New York, 296 p., 1988.) Journal of Environmental Quality 18(4):556 (1989).

No abstract.

AR-008

BALDOCCHI, D.D., and T.P. MEYERS. The effects of extreme turbulent events on the estimation of aerodynamic variables in a deciduous forest canopy. Agricultural and Forest Meteorology 48:117-134 (1989).

Heat, mass and momentum transfer, and the turbulence regime within a plant canopy, are dependent upon aerodynamic variables which are non-linearly related to wind speed. Measurements made in plant canopies show that turbulence is intermittent and non-Gaussian. Therefore, a statistical question arises when evaluating non-linear wind speed-dependent, aerodynamic variables: is the mean value of an aerodynamic function equal to that function evaluated at the mean wind speed? We evaluated the above-stated, statistical question for boundary layer resistances to mass and momentum transfer, the form drag force and the rate of work against form drag. Pertinent computations were based upon turbulence measurements made within a fully leafed, deciduous forest. In addition, expected values of these aerodynamic variables were computed with probability density functions derived from the Gram-Charlier expansion series. Boundary layer resistances for water vapor (R_v) and momentum (R_m), computed with mean wind speeds, underestimate mean functional values by 5-20%. On the other hand, estimates of R_v and R_m derived from probability density functions underestimate mean functional values by $< 3\%$. Computations of the form drag force, based on probability density functions and mean wind speeds, respectively, overestimate and underestimate mean functional values by $\sim 20\%$. Theoretically, the form drag force in the streamwise direction is a function of the product of the horizontal wind velocity and the scalar wind speed. Hence, parameterizing its value based only on scalar wind speed squared is apt to be error prone. Estimates of the rate of work against form drag, based on the probability density functions, agree within 5% of mean functional values. The rate of work against form drag computed on the basis of the mean horizontal wind speed cubed underestimates mean functional values by 30-60%. This underestimate, however, is expected since it represents the rate of work done by the mean wind, which is a different quantity.

AR-009

BALDOCCHI, D.D., R. White, and J.W. Johnson. A wind tunnel study to design large, open-top chambers for whole-tree pollutant exposure experiments. Journal of Air Pollution Control Association 39(12):1549-1556 (1989).

A wind tunnel study was conducted to determine the optimal design features of a large, open-top chamber, as needed for pollution exposure studies on mature trees. An optimally-designed, open-top chamber must minimize the incursion of ambient air through its opening and maintain a uniform treatment concentration throughout the chamber. The design features of interest are the diameter and height of the chamber and the deflection angle and opening size of any frustum that may be mounted on top of a model chamber. Design specifications depend on the turbulence regime about the chamber, which is influenced by the nature of the surrounding vegetation. Consequently, our investigation was performed on scale-model, open-top chambers in a wind tunnel populated with a model coniferous forest. Turbulence measurements demonstrated the similarity between the turbulence regime of the model and a natural forest. A hydrocarbon tracer was injected into the wind tunnel flow to characterize chamber performance. The main design features of open-top chambers are the velocity of air exiting through the top and the relationship between the length scale of the turbulence and the diameter of the chamber opening. As exit velocities increase, the proportion of eddies with sufficient force to penetrate into the chamber decrease. Therefore, for equal volumetric air flows, smaller opening sizes increase the exit velocities and reduce the number and extent of ambient air incursions. Almost total exclusion of ambient air is achieved as the exit velocity of the air exceeds the magnitude of one standard deviation of the vertical wind velocity measured at the chamber top. The incursion of ambient air is also reduced when the diameter of the chamber opening is smaller than the characteristic length scale of the turbulence, a measure of mean eddy size. Frusta deflect air flow over the chamber. Three prototypes, with 30-, 45- and 60-degree angles were tested. A 30-degree frustum slightly improves the performance of the chamber and is more effective in preventing ambient air from entraining into the chamber opening than frusta with either a 45- or 60-degree angle. A flatter frustum allows for a smoother transition in the wind velocity streamline and is less apt to cause wake turbulence, as is the case with steeper frusta. Knowledge of the turbulence characteristics of plant canopies are readily available in the literature and can aid scientists and engineers in designing the optimal chamber and frusta dimensions for their particular application. Therefore, the empirical approach to chamber design can be avoided, and substantial savings can be realized.

AR-010

BINKOWSKI, F.S., J.S. Chang, J.N. McHenry, S.D. Reynolds, and R.D. Cohn. Estimation of the annual contribution of US sulfur emissions to Canadian acidic deposition, and vice versa. Preprints, 18th International Technical Meeting of NATO-CCMS on Air Pollution Modelling and its Application, Volume 2, Vancouver, Canada, May 13-17, 1990. NATO/CCMS, Brussels, Belgium, 189-196 (1990).

No abstract.

AR-011

BOATMAN, J.F., N. Laulainen, J. Ray, C. VAN VALIN, L. GUNTER, R. Lee, D. Luecken, and K. Business. Acid precursor concentrations above the northeastern United States during summer 1987: Three case studies. Journal of Geophysical Research 95(D8):11,831-11,845 (1990).

Two aircraft measured the spatial distribution of SO_2, H_2O_2, O_3, and NO_y above the northeast United States during summer. The aircraft flew three missions between Columbus, Ohio and Saranac Lake, New York. The sulfur dioxide concentration averaged 1 - 2 ppbv within the planetary boundary layer (pbl) and <1 ppbv in the free troposphere. Superimposed on this background concentration were surface source regions with elevated concentrations as high as 14 ppbv. The hydrogen peroxide concentration averaged 2 - 4 ppbv, with the highest values found above the top of the boundary layer. The H_2O_2 pattern increased in both size and intensity above the top of the pbl during the afternoon. The ozone concentration varied between 30 and 110 ppbv. The concentration of O_3 increased by as much as 30 ppbv during the day. Nitrogen oxide concentrations were in the range <1 - 8 ppbv. The pattern of SO_2 and NO_y concentrations remained substantially the same during the daytime hours. The O_3 and NO_y concentrations were linked to surface emissions and photochemical processes. The ratio between H_2O_2 and SO_2 was >1, except in the lower pbl and near surface SO_2 source regions.

AR-012

BOATMAN, J.F., D.L. WELLMAN, W.D. Keene, and J.N. Galloway. An aerosol separator for use in aircraft. NOAA TM ERL ARL-179 (PB90-142217/AS), 21 pp. (1989).

An aerosol separator (cyclone) was developed to remove cloud drops or sea-salt particles from the air during research aircraft flights. The cyclone is made of stainless steel and its interior is completely coated with Teflon. It is able to process 1.9 m^3 min^{-1} of air at an inlet speed of 25 m s^{-1}. The inlet speed to the cyclone controls its efficiency and the particle separation size. A theoretical study suggests that the separator removes 90% of all particles greater than 1.1 μm in aerodynamic/Stokes diameter, provided their density is 1 g cm^{-3} and the inlet speed is 25 m s^{-1}. Laboratory work suggests that the separator removes all water drops larger than 0.5 μm in aerodynamic/ Stokes diameter at inlet speeds as small as 12 m s^{-1}. It removes dry particles larger than 0.8 μm in aerodynamic diameter at inlet speeds of 25 m s^{-1}. Field testing reveals that the separator removes all particles larger than 1.45 - 1.5 μm in aerodynamic/Stokes diameter. During flights near to the U.S. east coast, the aerosol separator removed the sea-salt sulfate from marine boundary layer samples. The sea-salt sulfate constituted about 2.2% of the total sulfate present. About 70% of the non-sea-salt sulfate mass was in the fine-mode (aerodynamic/Stokes diameter <1.45-1.5 μm). Between 25% and 30% of the non-sea-salt sulfate mass was in the coarse-mode (aerodynamic/Stokes diameter >1.45-1.5 μm).

AR-013

Breuninger, R.H., D.A. GILLETTE, and R. Kihl. Formation of wind-erodible aggregates for salty soils and soils with less than 50% sand composition in natural terrestrial environments. In Paleoclimatology and Paleometeorology: Modern and Past Patterns of Global Atmospheric Transport, M. Leinen and M. Sarnthein (eds.). Kluwer Academic, Dordrecht/Boston/London, 31-63 (1989).

Of nine possible mechanisms for the formation of non-sandy, wind-erodible aggregates from a more homogeneous soil or sediment, five are found to be widespread in arid and semiarid regions. In approximate order of significance, the most important mechanisms are tension and compression fracturing of shrinkable mud or soil during wet/dry cycles; tension fracturing and molding by compression during freeze/thaw cycles; direct abrasion (corrosion); fracturing and aggregation produced by salt efflorescence; and mechanical disturbance of surface materials by animals. A sixth mechanism (in soils) is by surface films, colloidal matting, or cements. Minor mechanisms are: floatation and lofting of foam and fracturing caused by hydration expansion or other chemical weathering of fine-grained bedrock. The flocculation of small particles in a water suspension or wet mud is a possible minor mechanism not yet observed. Surface soils and sediment; with more than 28% clay and more than 2% organic material formed wind-erodible aggregates, but organic-poor materials did not. Calcareous loams, silt loams, silty clay loams, and clay loams formed wind-erodible aggregates, but non-calcareous materials of the same textures did not. Salt efflorescence was locally a major mechanism for production of wind-erodible aggregates. An experiment with expandable (high smectite content) clay shows that wet/dry cycles (such as might result from several summer rain showers on a dry lake bed) can produce wind-erodible aggregates without high temperatures or lengthy droughts and in the absence of salt efflorescence. For example, cold-climate clay dunes (now inactive) fringe ephemeral lakes in deflation basins in Montana at windy semiarid sites with short hot summers and intensely cold winters.

AR-014

Brier, G.W., and K.J. HANSON. A nonparametric significance test of the solar-effect analysis of Labitzke and van Loon. Journal of Climate 2(11):1417-1418 (1989).

No abstract.

AR-015

BRIGGS, G.A. Flushing of dense gas from bottomlands by wind. Preprints, 18th International Technical Meeting of NATO-CCMS on Air Pollution Modelling and its Application, Volume 1, Vancouver, Canada, May 13-17, 1990. NATO/CCMS, Brussels, Belgium, 653 pp. (1990).

Extended abstract.

AR-016

BULLOCK, O.R., Jr. The effect of size-dependent dry deposition velocities in an Eulerian regional-scale particulate model. Preprints, 18th International Technical Meeting of NATO-CCMS on Air Pollution Modelling and its Application, Volume 1, Vancouver, Canada, May 13-17, 1990. NATO/CCMS, Brussels, Belgium, 145-152 (1990).

No abstract.

AR-017

Castro, I.P., W.H. SNYDER, and P.G. Baines. Obstacle drag in stratified flow. The Royal Society, London 429(A):119-140 (1990).

This paper describes an experimental study of the drag of two- and three-dimensional bluff obstacles of various cross-stream shapes when towed through a fluid having a stable, linear density gradient with Brunt-Vaisala frequency, N. Drag measurements were made directly using a force balance, and effects of obstacle blockage (h/D, where h and D are the obstacle height and the fluid depth, respectively) and Reynolds number were effectively eliminated. It is shown that even in cases where the downstream lee waves and propagating columnar waves are of large amplitude, the variation of drag with the parameter K (=ND/πU) is qualitatively close to that implied by linear theories, with drag minima existing at integral values of K. Under certain conditions large, steady, periodic variations in drag occur. Simultaneous drag measurements and video recordings of the wakes show that this unsteadiness is linked directly with time-variations in the lee and columnar wave amplitudes. It is argued that there are, therefore, situations where the inviscid flow is always unsteady even for large times; the consequent implications for atmospheric motions are discussed.

AR-018

CLARK, T.L., and R.D. Cohn. The Across North America Tracer Experiment (ANATEX) model evaluation study. EPA/600/3-90/051, Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, NC, 99 pp. (1990).

During the first three months of 1987, three perfluorocarbon tracer gases were released at 2.5-day or 5.0-day intervals from two sites in central North America (Glasgow, Montana and St. Cloud, Minnesota) and sampled for 24-h periods at 77 surface sites. The source-receptor distances ranged from less than 30 km to 3,000 km. These Across North America Tracer Experiment (ANATEX) data serve as a unique evaluation data set with which to evaluate the long-range transport and diffusion simulations of acid deposition models and to establish a range of uncertainty for various model genres. The performances of three single-layer Lagrangian, six multiple-layer Lagrangian, and two multiple-layer Eulerian models are assessed using quantifiable measures based on comparisons of ensemble mean concentrations and plume widths as well as trajectory errors expressed as a function of transport time. In general, the multiple-layer Lagrangian models performed best in simulating the transport of the tracers, while the Eulerian models performed best in simulating the ensemble concentration frequency distributions. After 0.5 day of transport, trajectory errors ranged from 100 km to 400 km; after 2.5 days, the errors ranged from 300 km to 800 km. Beyond 2.5 days, errors from four Lagrangian models plateaued, while errors for the other models continued to increase, peaking at nearly 1,100 km after 3.5 days. Of the three single-layer models, one performed as well as any other model in simulating the transport; the other two single-layer models performed worst. Thus, a slight difference in the method of calculating single-layer transport vectors can yield a significant difference in model performance. For six of the eleven models, the greatest errors in transport speed and location tended to occur when the tracer was intercepted by cyclones and/or fronts. The ensemble mean concentrations along three bands of sites 1,000 to 2,300 km downwind from the release sites were nearly always overpredicted by the single-layer Lagrangian models, in some cases by as much as a factor of 5; overpredictions by a factor of 3 were common. The two Eulerian models tended to underpredict these ensemble means by about 40%, especially along the nearest band. Finally, the multiple-layer Lagrangian models tended to underpredict the ensemble means for the tracer released from Montana, yet tended to overpredict the ensemble means for the tracer released from Minnesota. Horizontal spreading of the tracer plumes beyond 1,000 km transport distance occurred at a rate of 30% to 60% per 600 km. Generally the models replicated this spreading rate, although there was a wide range of plume widths. The plume widths of the Eulerian models tended to be the greatest, which partially explained their tendency to underpredict mean concentrations. In virtually all cases, the plume widths of the

Lagrangian models were equivalent to or less than the actual plume widths; for some models, plume widths were much less, by factors of 2 and 3.

AR-019

CLARK, T.L., and D.H. COVENTRY. Adaptation of the Advanced Statistical Trajectory Regional Air Pollution (ASTRAP) model to the EPA VAX computer -- modifications and testing. EPA/600/3-90/083, Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, NC, 36 pp. (1989).

The Advanced Statistical Trajectory Regional Air Pollution (ASTRAP) model simulates long-term transport and deposition of oxides of sulfur and nitrogen. It is a potential screening tool for assessing long-term effects on regional visibility from sulfur emission sources. A rigorous evaluation is required before this model can be recommended for this particular application; this can be accomplished after the 1988 and 1989 Acid Model Operational and Diagnostic Evaluation Study (ACID-MODES) data become available. As a first step, we modified the original IBM-3033 version of this model to create the ASTRAP-EPA version for applications on the EPA VAX-8600 computer using existing EPA preprocessed meteorological and emissions data files. Additional modifications improved the model design by eliminating several model assumptions and replacing some modeling approaches. The cumulative effect of the model modifications was assessed by comparing the quarterly 1980 calculations of sulfur wet deposition of both versions with screened measurements. The seasonal correlation coefficients and standard errors of each model version are insignificantly different at the 0.05 level, demonstrating that the two model versions indeed produce similar results. In general, the improvements in model design only slightly enhance model performance. Sensitivity of ASTRAP-EPA calculations of sulfur wet deposition was also assessed for several model assumptions and values of model parameters. ASTRAP-EPA model predictions are most sensitive to three parameters -- the model time step, the truncation of trajectories near the border of wind-data-void regions, and the temporal aggregation of ensemble trajectory statistics. The maximum quarterly predictions of sulfur wet deposition, across southwestern Pennsylvania and northern West Virginia, decrease by as much as 30% when either the model time step changes from 3 hours to 6 hours, or when trajectories are not truncated, or when trajectory statistics are not temporally aggregated.

AR-020

CLARK, T.L., E.C. Voldner, R.L. DENNIS, S.K. Seilkop, M. Alvos, and M.P. Olson. The evaluation of long-term sulfur deposition models. Atmospheric Environment 23:2267-2288 (1989).

The International Sulfur Deposition Model Evaluation (ISDME) assessed the performance of 11 regional, long-term deposition models in predicting amounts of sulfur wet deposition. With few exceptions, each model predicted air concentrations and dry/wet deposition amounts of SO_2 and SO_4^{2-} at up to 66 sites across eastern North America for each season of 1980. Unlike its predecessors, this evaluation focused on the ability of the models to replicate, within the uncertainty limits of the data, the magnitude and position of the seasonal spatial patterns of S wet deposition. Both the spatial patterns and the uncertainties arising from measurement and interpolation errors were determined by a simple Kriging technique. Model performance measures included the percent of subregions where interpolated predictions and observations were significantly different and differences between the magnitudes and locations of maxima, centroids and orientations of the major axes. When data uncertainty limits are considered, the seasonal predictions of one Lagrangian and two statistical models were insignificantly different from the seasonal observations (at approximately the 95% confidence level) across at least 85% of the evaluation region. Three other models performed relatively well for two or three seasons, while the performance of three others was somewhat erratic. The final two models significantly underpredicted for every season across at least 40% of the evaluation region. In spring, all of the models correctly predicted the location of the observed maximum amount of S wet deposition. For the other three seasons the models predicted the locations within 170-350 km. Except for summer, most models predicted the magnitude of the observed maximum within the data uncertainty limits.

AR-021

CRAWFORD, T.L., R.T. MCMILLEN, and R.J. Dobosy. Development of a "generic" mobile flux platform with demonstration on a small airplane. NOAA TM ERL ARL-184 (PB90-268236), 83 pp. (1990).

The theory, instrumentation and demonstration of a "generic" Mobile Flux Platform (MFP) to measure atmospheric turbulent structure and trace-gas air-surface exchange are described. This development responds to research needs for a low cost system capable of measuring representativeness and spatial variability of air-surface exchange over various ecosystems. The MFP was demonstrated on a small single engine airplane. For this demonstration, the system was configured to measure position, mean temperature, wind, and the fluxes of momentum, heat, moisture, carbon dioxide, and ozone. Additionally, low-frequency sensors document pressure altitude, radar altitude, incoming short-wave radiation, net radiation, and infrared surface temperature. The MFP described is novel in approach, and was designed to be a small low cost, generic "strap down" system. Specific applications require a platform-specific turbulence velocity probe. The low cost and practical nature of ATDD's MFP was made possible by recent technological advances in both low cost miniature sensors and computer technology. Small sensors allowed co-location of both the air velocity and motion sensors. This allows direct measurement of probe motion instead of platform motion. Modern computer technology allows not only channel input, data rate, and storage flexibility, but also mathematical rotation from platform to earth coordinates. Airborne platform utility also benefits from modern technology by use of a

high performance canard airplane which is inexpensive to operate and aerodynamically well suited for high fidelity turbulent flux measurements.

AR-022

Daum, P.H., L.I. Kleinman, A.J. Hills, A.L. Lazrus, A.C.D. Leslie, K. Busness, and J. BOATMAN. Measurement and interpretation of concentrations of H_2O_2 and related species in the upper midwest during summer. Journal of Geophysical Research 95(D7):9857-9871 (1990).

Measurements of H_2O_2 and related species were made by aircraft on 18 flights over 11 days during June 1987 over Ohio. Measurements typically encompassed an altitude range from the surface to 5.5 km above mean sea level and were conducted under a variety of meteorological conditions but focused on conditions conclusive to the formation of convective storms. Concentrations of H_2O_2 ranged from <0.2 to 7 ppb and exhibited as much as a factor of 10 variability even on a given day at fixed altitude, as well as between days. Hydrogen peroxide concentration typically was low near the surface, rose to a maximum near the top of the boundary layer, then slowly decreased with altitude. In contrast, SO_2 and NO_y were largely confined to the surface layer. A simple photochemical calculation shows that where NO_x concentrations are low $[H_2O_2]$ is strongly influenced by the water vapor concentration. The $[H_2O_2]$ tracked changes in dew point, and measured and calculated H_2O_2 concentrations were in general agreement. The low $[H_2O_2]$ in the boundary layer is ascribed to consumption of radicals by reactions other than combination reactions, and to loss of H_2O_2 by dry deposition. Comparison of the profile shapes for H_2O_2 and SO_2 suggests that mixing processes will have a large influence on the extent to which these two species will react in convective systems.

AR-023

DENNIS, R.L., J.N. McHenry, D.W. Byun, T.L. CLARK, and S.D. Reynolds. Delineation of the influence of major emissions regions on the annual acidic deposition at sensitive areas. Preprints, 18th International Technical Meeting of NATO-CCMS on Air Pollution Modelling and its Application, Volume 1, Vancouver, Canada, May 13-17, 1990. NATO/CCMS, Brussels, Belgium, 105-112 (1990).

No abstract.

AR-024

DENNIS, R.L., J.N. McHenry, S.K. Seilkop, and J.S. Chang. Characterization of the nonlinear change in annual sulfur deposition for a change in emissions. Preprints, 18th International Technical Meeting of NATO-CCMS on Air Pollution Modelling and its Application, Volume 1, Vancouver, Canada, May 13-17, 1990. NATO/CCMS, Brussels, Belgium, 113-120 (1990).

No abstract.

AR-025

Dobosy, R.J. Modeling bulk atmospheric drainage flow in a valley. Journal of Applied Meteorology 28(9):936-947 (1989).

Most simulations of bulk valley-drainage flows depend heavily on parameterizations. The 1984 Atmospheric Studies in Complex Terrain (ASCOT) field experiment in Brush Creek Valley, Colorado, provided an unprecedented density of measurements in a natural valley of simple shape, allowing tests of assumptions and parameterizations developed from laboratory measurements and detailed numerical simulations. This paper uses the ASCOT data to test a model that computes total fluxes of mass (volume) and momentum--determining buoyant and pressure-gradient forces from measured temperature profiles, and parameterizing drag, entrainment, and sidewall and tributary drainage. Computed divergences of volume and momentum flux are within a factor of 2 of the Doppler lidar measurements in Brush Creek Valley. The relative importance of individual terms as parameterized in the model is discussed. A major problem for future work is the treatment of the interaction between valley drainage and ambient flow.

AR-026

Dobosy, R.J., K.S. RAO, J.W. Przybylowicz, R.M. ECKMAN, and R.P. HOSKER, JR. Mass and momentum balance in the Brush Creek drainage flow determined from single-profile data. Journal of Applied Meteorology 28:467-476 (1989).

Fluxes and flux-divergences of mass and momentum in Brush Creek Valley, computed from measurements taken by tethersondes and Doppler sodars in the 1984 ASCOT experiment, are presented. Estimates of mass influx from open sidewalls in Brush Creek, derived from concurrent tower measurements, are also given. Mass and momentum fluxes calculated from single-profile data were within a factor of 1.5 of those obtained by integrating Doppler lidar data. Flux-divergences for budget calculations should be derived from a Doppler lidar or equivalent remote sensor data, because single-profile measurements were found to have sampling errors which are too large for reliable flux divergence estimates. The mass influx from the sidewalls was insufficient to account for the mass flux-divergence in the main valley. This

imbalance in the drainage flow mass budget is speculated to be due to the inflow from the small box-canyon tributaries, rather than from subsidence of air above the main valley.

AR-027

DRAXLER, R.R. The calculation of low-level winds from the archived data of a regional primitive equation forecast model. Journal of Applied Meteorology 29(3):240-248 (1990).

Meteorological data fields from NOAA's Nested Grid Model (NGM) were archived at 2 h intervals from initialization to the 12 h forecast time, two forecasts per day, for January, February, and March of 1987. The NGM predictions of the winds at the lowest level (175 m) and predictions of surface momentum and sensible heat flux were used in a separate boundary layer model (BLM) to derive values of wind speed and direction between the surface and the lowest NGM level. BLM results were compared with measurements made on Savannah River Laboratory's meteorologically instrumented 366 m TV tower in Beech Island, South Carolina and the nearby Augusta, Georgia weather station. The comparison between predicted and measured wind speeds and directions was quite favorable in that the forecast model was able to reproduce the diurnal variations at all levels of the tower. However, the BLM underpredicted the mean tower wind speed profile by about 20% (1 m/s) at most levels of the tower. Diurnal variations of wind speed of 4 m/s at the top of the tower to less than 0.5 m/s at the bottom were well predicted at all levels, with the predicted maximums and minimums occurring at the appropriate times. Wind direction changes of 25 deg at night and less than 10 deg during the day were similarly predicted, however predicted wind directions were biased by about +10 deg compared with the tower measured wind directions.

AR-028

DRAXLER, R.R., and A.D. TAYLOR. An advective-interpolation method for estimating pollutant movement during ANATEX. Atmospheric Environment 24A(2):431-433 (1990).

A temporal interpolation technique has been developed that uses meteorological information to show the evolution of an average air concentration pattern into its next time period average. Forward and backward trajectories are constructed from every point at the desired time to the next and previous time period patterns. The concentration is then the weighted average of the concentrations at the respective trajectory endpoints. The technique can be used to smooth transitions between successive images for movie animation or video presentations. An example sequence from the ANATEX video is shown.

AR-029

ECKMAN, R.M. The suitability of dense-contaminant models for emergency preparedness systems. NOAA TM ERL ARL-182 (PB90-235730), 19 pp. (1990).

Many hazardous atmospheric contaminants are denser than air, so an emergency preparedness system should be able to simulate the transport and diffusion of such contaminants. Over the past two decades a number of modeling techniques have been developed to estimate the transport and diffusion of dense contaminants. In this report the suitability of these modeling techniques for an emergency preparedness system is examined. None of the currently available models is entirely suitable for emergency preparedness, because the models are either too complex to run in real time or are too restricted in their applicability to different atmospheric conditions and terrain features. It is recommended that a puff model be used in an emergency preparedness system to simulate the transport and diffusion of both passive and dense contaminants. But when the contaminant is dense, the puffs should initially be cylindrical, and a similarity model for cylindrical dense puffs should be used to simulate the initial diffusion.

AR-030

EDER, B.K. A principal component analysis of SO_4^{2-} precipitation concentrations over the eastern United States. Atmospheric Environment 23:2739-2750 (1989).

The spatial and temporal variability of SO_4^{2-} concentrations in precipitation over the eastern U.S. during the period 1981-1986 was examined through the use of principal component analysis. Application of Kaiser's Varimax orthogonal rotation led to the delineation of seven contiguous subregions, each displaying statistically unique SO_4^{2-} concentration characteristics. These seven statistically significant modes of variability, which together accounted for 74.2% of the total variance, corresponded well with major SO_x emission patterns. Examination of the time series associated with each subregion revealed a general seasonality in which periods of high concentrations are more likely during the summer, while periods of low concentration are more likely during the winter. This seasonal cycle, however, was more prevalent in those subregions which contained few major emissions, and was less prevalent and often obscured by perturbations in those subregions which contained major emissions.

AR-031

ESKRIDGE, R.E., B. Lamb, and E. Allwine. Velocity oscillations plume dispersion in a residential neighborhood during wintertime nights. Atmospheric Environment 24A:1781-1796 (1990).

Measurement of velocity and tracer plume concentrations during stable atmospheric conditions were obtained in the Boise River Valley as part to the EPA Integrated Air Cancer Project during December, 1986. Wind speed, temperature, and wind direction were measured at two levels on a 30 m tower. Spectral and autocorrelation analyses of the velocity component data clearly indicate the occurrence of wave-like oscillations in the flow and the almost complete lack of turbulent energy. The predominate wave-like motion had an oscillation period of about 1000 s. Halogenated atmospheric tracers were released from as many as four houses during the night-time drainage conditions. Hourly averaged horizontal dispersion coefficients were very large compared to the Pasquill-Gifford curves and the urban McElroy-Pooler dispersion curves. The time-averaged dispersion coefficients formed an upper bound on very short-term dispersion coefficients obtained from mobile traverses of the tracer plume with a continuous SF_6 analyzer. These results agree with the concept of a narrow instantaneous plume with a broad meander driven by the observed 1000 s oscillation. Vertical dispersion rates were slightly smaller than the Pasquill-Gifford class F curve. Results from a single tracer release from a side canyon near the neighborhood showed that drainage flow from the tributary impacted the main residential sampling site a Elm Grove Park and represented a significant fraction of the upstream air flow at Elm Grove Park. For sources with equal emission rates, a source in the tributary adds about 10% to the mean of the concentration caused by a neighborhood source.

AR-032

Galloway, J.N., W.C. Keene, R.S. ARTZ, J.M. MILLER, T.M. Church, and A.H. Knap. Processes controlling the concentrations of $SO_4^=$, NO_3^-, NH_4^+, H^+, $HC00_T$ and CH_3COO_T in precipitation on Bermuda. Tellus 41(B):427-443.

The comparison of precipitation on Bermuda can be characterized as a slightly acidic, dilute seawater solution. The acidity of the solution is controlled by H_2SO_4, HNO_3, HCOOH and CH_3COOH in a 67:20:8:3 mixture, respectively. $CaCO_3$ and NH_3 have reduced the potential acidity of the solution by 24% and 13%, respectively. The concentrations of non-sea-salt (nss) $SO_4^=$ and NO_3^- on precipitation in Bermuda are about a factor of three greater than those in remote marine areas of the world. These differences are attributed in part to anthropogenic activities. $NH4^+$ $HCOO_T$ and CH_3COO_T concentrations in Bermuda precipitation more closely resemble remote areas, although there are distinct events where transport from North America is evident. Precipitation associated with air masses from the central Atlantic Ocean is enriched relative to remote marine areas by about a factor of two in nss $SO_4^=$. This appears to be caused by anthropogenic emissions in North America, Europe and Africa. There are higher volume-weighted average concentrations of nss $SO_4^=$ and NO_3^- in storms on Bermuda associated with the NW airflow sector (from North America) compared to the SE airflow sector. These higher concentrations are in part due to the influence of North America and in part due to lower amounts of precipitation in the NW storms. An analysis of deposition differences between the two sectors confirms that there is at least a factor of two impact of North American anthropogenic activities on nss $SO_4^=$ and NO_3^- in precipitation on Bermuda.

AR-033

Garratt, J.R., and B.B. HICKS. Micrometeorological and PBL experiments in Australia. Boundary-Layer Meteorology 50:11-29 (1990).

A brief summary is given of the five main field experiments (or sets of expeditions) carried out in Australia in the last thirty years. The main objectives and results of each are described, and an indication is given of their impact on progress in our understanding of the planetary boundary layer (PBL).

AR-034

GILLETTE, D.A., and P.C. Sinclair. Estimation of suspension of alkaline material by dust devils in the United States. Atmospheric Environment 24A(5):1135-1142 (1990).

Estimates are made of the contribution of dust devils to the aerosol mass burden over the U.S. These estimates have been derived from experimental data generalized by using climatic and vegetation maps of the U.S. The area of maximum calculated dust production by dust devils is the southwestern U.S. Comparison of calculated fluxes with background aerosol data shows general agreement. Comparison of alkaline dust emissions from wind erosion shows that dust devils provide a similar magnitude input of atmospheric dust.

AR-035

GILLETTE, D.A., and P.H. Stockton. The effect of nonerodible particles on wind erosion of erodible surfaces. Journal of Geophysical Research 94(D10):12885-12893 (1989).

Nonerodible elements on erodible surfaces have the effect of absorbing part of the wind momentum flux (stress) and thus protect the erodible surface to a degree, depending on the geometry of the mixture. Experiments measuring the effect of nonerodible elements show

that these elements increase the apparent threshold velocity of erosion and that the functional form of the mass flux (of erodible sand particles) in terms of friction velocity follows an Owen function. The partitioning of momentum flux by the nonerodible elements is smaller in our experiments than measured in the experiments of Marshall; however, in those measurements for which nonerodible geometry is similar, our results are roughly consistent with the experimental results of Lyles et al. The disagreement with the Marshall results is tentatively explained by differences in scale and in the wind stress measuring systems.

AR-036

GODOWITCH, J.M. Vertical ozone fluxes and related deposition parameters over agricultural and forested landscapes. Boundary-Layer Meteorology 50:375-404 (1990).

The spatial variability and temporal behavior of the vertical flux of ozone have been investigated from turbulence measurements collected on aircraft flight legs in the daytime period during two consecutive summer experimental field programs. The data were obtained during horizontal flight legs conducted over agricultural crops and forested land in three different regions of the eastern United States. Results from individual experimental cases and statistics derived from all cases in each region are presented. Ozone flux generally exhibited a significant height dependency. The strongest negative (downward) fluxes in the lowest-level flight legs were primarily attributed to the uptake of ozone by the surface and vegetative cover. Fluxes were near-zero in the middle of the convective boundary layer (CBL) in the afternoon period. As ozone flux was proportional to concentration, slightly stronger fluxes were found in low-level urban plume segments where ozone concentrations were 10-20 ppb higher than in the surrounding area. The derived deposition velocity showed no such bias as a function of position across the urban plume. Ozone flux differences were not apparent between the more heavily forested sections and the primarily agricultural cropland areas in these regions. During the afternoon period when no clear temporal trend was evident, means from values obtained below $0.15Z_i$ (Z_i being the CBL height) were -0.421 and -0.431 ppb m^{-2} s^{-1} for ozone flux and 0.81 and 0.82 cm s^{-1} for the derived mean deposition velocity in the southeastern Pennsylvania and central Ohio areas, respectively. These experimental results for ozone provide support to a dry deposition parameterization module which computes grid-area averaged deposition velocities for use in regional-scale models.

AR-037

Gudiksen, P.H., W.E. Clements, R.P. HOSKER, JR., C.D. Whiteman, W.D. Neff, R.L. Coulter, and G.E. Start. Field studies for determining the characteristics and dynamics of local circulations. Contract Report No. W-7405-Eng-48, U.S. Department of Energy, 35 pp. Preprints, 2nd International Workshop on Real-Time Computing of the Environmental Consequences of an Accidental Release to the Atmosphere from a Nuclear Installation, Luxembourg, May 15-19, 1989. Commission of European Communities, Brussels, 251-285 (1990).

No abstract.

AR-038

GUNTER, R.L., and J.F. BOATMAN. Aircraft measurements of pollution species near Bermuda and the east coast of the United States during CASE-WATOX. NOAA TM ERL ARL-176 (PB90-159450/AS), 75 pp. (1989).

Chemical, meteoroiogical, and aerosol measurements were made with the NOAA King Air C-90 aircraft during July 1988 near Bermuda and the east coast of the U.S. The study extended the 1985 and 1986 Western Atlantic Ocean Experiment (WATOX), and initiated coordinated aircraft and ship measurements, following the design of the Coordinated Air Sea Experiment (CASE), in which flights were planned to be made in the vicinity of the NOAA ship Mt. Mitchell. This report lists the objectives of the CASE-WATOX program; the instrumentation used, and the data obtained with the aircraft; a general outline of ship and aircraft coordination and instrumentation; and the aircraft data processing, quality and availability.

AR-039

HANSON, K., G.W. Brier, and G.A. Maul. Evidence of significant nonrandom behavior in the recurrence of strong El Nino between 1525 and 1988. Geophysical Research Letters 16(10):1181-1184 (1989).

The precise character of the quasi-periodic variation in the recurrence of El Nino events has been unclear. To gain insight into the nature of this apparent regularity, a 464-year record (1525-1988) of the initiation of "strong" El Nino events, derived from the chronology of Quinn et al. [1987], has been analyzed with a two-dimensional extension of the periodogram analysis method of Buys Ballot. The method is useful for detecting joint nonlinear interactions between variations at two specified periods. Results indicate joint nonrandom recurrence of strong El Nino events at periods of 6.75 and 14.0 years. From Monte Carlo tests, we estimate the statistical significance of this result to be at the 0.1% level. Alternating ~95 year-long time-blocks, where 6.75-year and 14.0-year recurrence periods dominate, is apparent from the analysis. No specific mechanism is offered for the periodic forcing of strong El Nino events, but our observation of significant quasi-periodic behavior in the initiation of such events at the combined periods of 6.75 and 14.0 years may be a useful clue in efforts to understand and model natural ENSO recurrence.

AR-040

HANSON, K., and T. Stoffel. Solar radiation monitoring networks. In Solar Resources, R.L. Hulstrom (ed.). The MIT Press, Cambridge, MA, 143-171 (1989).

No abstract.

AR-041

HEFFTER, J.L., and R.R. DRAXLER. Across North America Tracer Experiment (ANATEX) Volume III: Sampling at tower and remote sites. NOAA TM ERL ARL-175 (PB90-188699), 67 pp. (1989).

The Across North America Tracer Experiment (ANATEX) was designed to provide a comprehensive data base for assessing the performance of long-range transport and diffusion models. Three distinct perfluorocarbon tracers (PMCH, oPDCH, and PTCH) were released simultaneously for a 3-h duration every 2 1/2 days from 2 sites; PTCH from Glasgow, Montana, and oPDCH and PMCH (every fifth day) from St. Cloud, Minnesota for the 84-day period January 5, 1987 through March 29, 1987. Daily (24-h) average ground-level tracer measurements were taken at 77 "primary" sampling sites located about 500 to 3000 km from Glasgow. In addition, 6-h measurements were taken at the base and top of 5 tall towers (~200 m) and 24-h measurements were taken at the tower tops along the ANATEX 1600 km arc to investigate the vertical tracer distributions with respect to nearby ground-level sample collections. The ANATEX sampling program also included weekly average measurements at 12 "remote" sites in the western Atlantic, the west coast of Europe, and the west coast of North America to investigate very long-range plumes and hemispheric tracer background. This report describes the experimental design of the sampling programs at the tower and remote sites, discusses the measured data and how they were analyzed and quality assured, summarizes data characteristics, discusses data use, and presents complete data tables for both tower and remote sites. The report also describes the characteristics, format, and accessibility of data sets created from the data analysis.

AR-042

HICKS, B.B. Overview of deposition processes. In The Role of Nitrogen in the Acidification of Soils and Surface Waters. Nordic Council of Ministers, Denmark and U.S. Environmental Protection Agency, J.L. Malanchuk and J. Nilsson (eds.), 3-1 - 3-21 (1989).

No abstract.

AR-043

HICKS, B.B. Regional extrapolation: Vegetation-atmosphere approach. In Exchange of Trace Gases between Terrestrial Ecosystems and the Atmosphere, M.O. Andreae and D.S. Schimel (eds.). John Wiley & Sons Ltd., Chichester, 109-118 (1989).

Available data on the exchange of trace gases from the surface into the atmosphere is generated primarily by methods that yield locally representative flux information over short time intervals. On the other hand, regional-scale and global models require exchange data averaged over grid cells that are typically 100 km x 100 km, or larger. The extension from local data to grid-cell averages is far from trivial. Micrometeorological formulations of atmosphere-surface exchange are potentially well suited for use in such extrapolation, because they describe area averages at the outset (usually several hectares) and include descriptions of the terrain and vegetation properties that influence the exchange. However, these formulations lack the biological and chemical detail provided by models developed as a consequence of laboratory studies of soils and vegetation, and of field studies using curvettes and chambers. Methods required, therefore, to include the detail of these biological and chemical models in the micrometeorological routines, and then to use the modified micrometeorological methods to produce area averages. Here, methods are proposed for both purposes, based on the techniques developed to describe fundamental characteristics of vegetation in atmospheric models. This, then, constitutes the "Vegetation-Atmosphere Approach" of the title of this chapter. Micrometeorological relationships are presented in a format that offers an opportunity to include the results of detailed point-by-point emission models in their specification of appropriate zero plane displacements, roughness lengths, and average surface-air concentrations. Extension to larger areas is then proposed to make use of a replicated application of the modified micrometeorological relations that are derived.

AR-044

HICKS, B.B., D.R. MATT, R.T. MCMILLEN, J.D. Womack, M.L. Wesely, R.L. Hart, D.R. Cook, S.E. Lindberg, R.G. de Pena, and D.W. Thomson. A field investigation of sulfate fluxes to a deciduous forest. Journal of Geophysical Research 94(D10):13,003-13,011 (1989).

An intensive investigation of particulate sulfur fluxes to a deciduous forest was conducted at Oak Ridge, Tennessee, during May 1983, as part of a multilaboratory program to study the dry deposition of airborne trace gases and aerosols to vegetated surfaces. At this time, the leaf area was approximately 50% of the maximum and rapidly increasing. Eddy correlation methods were used to measure fluxes of submicron particulate sulfur (presumably sulfate), of submicron particles in three different size ranges, and of ozone above the forest

canopy. The measured deposition velocities (v_d) of particulate sulfur peaked at about 1 cm s^{-1} in daytime, but dropped to near zero at night, with a long-term average of about 0.6 cm s^{-1}. When scaled with friction velocity, these values of v_d are consistent with similar measurements taken previously over different surfaces. Measurements and analyses indicate that the flux divergence of particulate sulfur should have caused an error no greater than ± 0.05 cm s^{-1} in v_d estimates. For very small particles (less than 0.1 μm diameter), measured values of v_d were similar to those for particulate sulfate, but deposition velocities for particles in the accumulation size range decreased as particle size increased, and upward components of fluxes were found in daytime convective conditions. During this study, measurements were also made of sulfur deposition to polycarbonate petri dishes placed in the forest canopy, and to the bucket of a standard wet-dry collector in a forest clearing. These surrogate surface studies produced much smaller values of v_d for sulfate than those derived from eddy correlation, when no scaling as a function of leaf area relative to ground area was applied.

AR-045

Horvath, H., R.L. GUNTER, and S.W. WILKISON. Determination of the coarse mode of the atmospheric aerosol using data from a forward-scattering spectrometer probe. Aerosol Science and Technology 12:964-980 (1990).

The coarse mode of the atmospheric aerosol, containing mostly particles larger than 1 μm in diameter, can conveniently be measured by means of an optical-forward-scattering spectrometer probe mounted on an airplane. Although the instrument is able to count single particles, at least 10,000 particles have to pass the sensitive volume in order to reduce errors due to statistical fluctuations of the counts, especially in the bins of the larger particles. The fitting of a lognormal curve to the measured particle counts is possible by means of a least-squares technique, described in this paper. The quality of the fit can be examined by determination of the best fit for the particle number distribution and the particle volume distribution, and an intercomparison of the two. Data for atmospheric samples show geometric mean diameters for the number size distribution between 1 and 2.5 μm and standard deviations between 1.7 and 2.5. Aerosols dominated by one source have a small standard deviation. Standard deviations larger than 2.5 are an indication of an aerosol coming from several sources and in many cases a good fit can be obtained by using two lognormal distributions.

AR-046

HUBER, A.H. The influence of building width and orientation on plume dispersion in the wake of a building. Atmospheric Environment 23:2109-2116 (1989).

In a wind-tunnel study, the influence of building width and orientation into the wind was examined through concentration profiles in the near wake of the building. The model building was placed in a simulated atmospheric boundary layer. The effects of building width were examined for buildings have width-to-height ratios ranging from 2 to 22. The effects of oblique orientation were examined for angles ranging from -30 to +60 deg. For most cases, the source was placed midway along the lee side of the building. The stack height was either at ground level or 1.5 times the height of the building. The lateral plume spread from a point source placed near the center of the building was observed to be largest for a width/height ratio of 10. The influence of the end flow around the sides of the building had less effect for wider buildings. For the ground-level source, an oblique angle resulted in a maximum ground-level concentration increase by a factor of 2-3 at three building heights downstream. Concentrations were increased by less than a factor of 1.5 at ten building heights downstream. For an elevated source, the building influence on ground-level concentrations was quite similar but with an even larger increase.

AR-047

HUBER, A.H, and S.P.S. Arya. Video images of smoke dispersion in the near wake of a model building. Part II. Cross-stream distribution. Journal of Wind Engineering and Industrial Aerodynamics 32:263-284 (1989).

No abstract.

AR-048

IRWIN, J.S., A.H. HUBER, and W.B. PETERSEN. Estimating exposures downwind of isolated buildings. Proceedings, 1990 EPA/A&WMA International Symposium on Measurement of Toxic and Related Air Pollutants, Raleigh, NC, April 30 - May 4, 1990. U.S. Environmental Protection Agency, Research Triangle Park, NC, and Air & Waste Management Association, Pittsburgh (1990).

No abstract.

AR-049

IRWIN, J.S., and J.O. Paumier. Meteorological Processor for Regulatory Models (MPRM-1.2-User's Guide). EPA/600/8-88/043 (Revised), Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, NC, 219 pp. (1990).

In September 1988, version 1.1 of a Meteorological Processor for Regulatory Models was made available. In January 1990, in the course of following up on an inquiry from a user of the processor, an error was discovered in the FORTRAN coding. National Weather Service (NWS) hourly observations of wind direction and speed were being handled improperly. As a result of the error, calm wind conditions, encoded within the NWS observation as zero wind speed and zero wind direction, were being treated by the processor as missing data. This forced users to perform the calm wind adjustment procedures themselves. The processor encodes missing wind speeds as -9 and missing wind directions as -99. Whereas, calm winds are adjusted such that the wind speed is set to 1 m s^{-1} and the wind direction is set equal to the last valid wind direction. The FORTRAN changes to correct the error only affected one subroutine WSINWS. To reflect that a change had been made to the model, the model version number was changed from 1.1 to 1.2 A new section was added to the MPRM user's guide entitled, Revision History. The purpose of this section is to record when revisions occur and to briefly indicate the nature of the revision. No text changes of a technical nature were required.

AR-050

Johnson, T.C., R.D. Stieglitz, and A.M. Swain. Age and paleoclimatic significance of Lake Michigan beach ridges at Baileys Harbor, Wisconsin. Proceedings, Late Quaternary History of the Lake Michigan Basin, Boulder, CO. Geological Society of America, Special Paper 251, 67-74 (1990).

A complex of abandoned Lake Michigan beach ridges at Baileys Harbor, Wisconsin was investigated to establish the type, onset, and periodicity of ridge-forming processes. A further objective of the study was to place the development of the complex into the context of the postglacial history of the Great Lakes region. Surface profiles were constructed, and samples of sediment and peat were collected and analyzed. Results of pollen and radiocarbon analyses were used to infer the kind and timing of climatic conditions affecting lake levels, ridge accretion, and peat accumulation. A suggestion is made for an asymmetrical rate of change between high and low lake levels. The ridges accreted during four episodes of low or falling lake levels separated by three periods of high or rising water, during which erosion of earlier ridges occurred. Peat first began to accumulate in the interridge swales after the first erosional event, and construction of a truncating ridge began not long before 1,000 B.P. A pollen core extracted from behind the oldest ridge revealed a vegetational sequence that closely corresponds with post-Algoma lake-level fluctuations reported by other workers for the Lake Michigan basin.

AR-051

Khrshudyan, L.H., W.H. SNYDER, I.V. Nekrasov, R.E. LAWSON, JR., R.S. Thompson, and F.A. SCHIERMEIER. Flow and dispersion of pollutants within two-dimensional valleys: Summary report on joint Soviet-American study. EPA/600/3-90/025, Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, NC, 85 pp. (1989).

Wind-tunnel experiments and a theoretical model concerning the flow structure and pollutant diffusion over two-dimensional valleys of varying aspect ratio are described and compared. Three model valleys were used, having small, medium, and steep slopes. Measurements of mean and turbulent velocity fields were made upstream, within, and downwind of each of these valleys. Concentration distributions were measured downwind of tracer sources placed at an array of locations within each of the valleys. The data are displayed as maps of terrain amplification factors, defined as the ratios of maximum ground-level concentrations in the presence of the valleys to the maxima observed from sources of the same height located in flat terrain. Maps are also provided showing the distance to locations of the maximum ground-level concentrations. The concentration patterns are interpreted in terms of the detailed flow structure measured in the valleys. These data were also compared with results of a mathematical model for treating flow and dispersion over two-dimensional complex terrain. This model used the wind-tunnel measurements to generate mean flow fields and eddy diffusivities, and these were applied in the numerical solution of the diffusion equation. Measured concentration fields were predicted reasonably well by this model for the valley of small slope and somewhat less well for the valley of medium slope. Because flow separation was observed within the steepest valley, the model was not applied in this case.

AR-052

Kim, Y.J., and J.F. BOATMAN. Size calibration corrections for the active scattering aerosol spectrometer probe (ASASP-100X). Aerosol Science and Technology 12:665-672 (1990).

The response of the active scattering aerosol spectrometer probe (ASASP-100X) is affected by the optical properties of measured particles. Response functions of the ASASP-100X probe were calculated for different complex refractive indices corresponding to different types of atmospheric aerosol particles under various relative humidity conditions. Based on these response functions, corrected calibration bin diameters were determined for 15 size channels at six relative humidity values (0%, 50%, 70%, 80%, 90%, and 99%) and three typical aerosol types (rural, urban, and maritime). Sample calculations with these corrected calibration data show that a significant underestimation of the aerosol volume distribution can result if uncorrected manufacturer's size calibration data are used.

AR-053

Kok, G.L., A.J. Schanot, P.F. Lindgren, P.K. Dasgupta, D.A. Hegg, P.V. Hobbs, and J.F. BOATMAN. An airborne test of three sulfur dioxide measurement techniques. Atmospheric Environment 24A(7):1903-1908 (1990).

Measurements of sulfur dioxide (SO_2) were made from an aircraft over the Eastern Colorado Plains in August of 1988. Three different SO_2 measurement techniques were used. A high-flow filter pack collection system was operated by the University of Washington, a diffusion denuder/ion chromatography system by Texas Tech University and a commercial pulsed fluorescence SO_2 analyzer was operated by the Air Resources Laboratory of NOAA. Measurements ranged from less than 0.1 ppbv to in excess of 1 ppbv. Although measurements from the three techniques showed considerable scatter, all three sets of measurements were significantly correlated.

AR-054

Lamb, X.F. Zhang, R.E. ESKRIDGE, R. Brenner, H. Westberg, J. Mitchell, Z. Xiacheng, and L. Jun. Elevated plume transport and dispersion: 20-150 km downwind of Beijing, P.R.C. Atmospheric Environment 24A:859-870 (1990).

Three mobile continuous analyzers and an array of fixed sequential syringe samplers were used to measure plume dispersion rates of SF_6 released from a 300 m tower in Beijing during strong steady winds with neutral conditions. The plume trajectories over the flat, open terrain downwind of Beijing were relatively straight. Predicted plume trajectories based on interpolated wind fields from surface and upper air data exhibited a mean separation error of 4 km at 70 km downwind. Maximum predicted concentrations from a Gaussian puff model agreed with a factor of 2 with observed surface profiles when the source was given an initial vertical distribution to account for the effects wind shear upon horizontal dispersion. Short-term (i.e., 10-20 min averaging time) horizontal dispersion rates were essentially equal to the neutral Pasquill-Gifford curve. Dispersion coefficients from hourly averaged concentration profiles were 30% larger than the PG neutral curve, but 50% smaller than a linear neutral curve based upon dispersion data collected downwind of a power plant. Hourly averaged σy calculated from: $\sigma_y u/\sigma_v x = [1+0.9(x/uT_L)^{1/2}]^{-1}$ where $T_L = 15{,}000$ s were in good agreement with the observed dispersion coefficients at distances of 30 km and were 20% smaller than observed at distances of 70 km.

AR-055

LAWSON, R.E., Jr. Concentration distributions in the near-wake of a building. Preprint, Ninth Symposium on Turbulence and Diffusion, Roskilde, Denmark, April 30 - May 3, 1990. American Meteorological Society, Boston, 37 pp. (1990).

A set of wind-tunnel data is presented which describes the concentration distributions resulting from diffusion of a passive tracer in the near-wake of a cubical building. Sources were located near ground level both upstream and downstream of the building, and centered atop the building. Ground-level centerline concentrations predicted by several simple models for dispersion in building wakes were compared with the measured wind-tunnel data in order to determine the limits within which such models could be expected to provide acceptable predictions. The Huber-Snyder model was found to provide very good agreement with the ground-level centerline concentrations, but at the expense of underpredicting the lateral plume spread. The Ferrara-Cagnetti model provided better agreement with observed plume spreads, but underpredicted the observed concentrations. Based upon observations of transport speed in the wake of similar obstacles, a simple modification to the Ferrara-Cagnetti model is suggested which improves the prediction of concentrations while still providing reasonable estimates of the plume spread. The application of various types of building-wake diffusion models is briefly summarized.

AR-056

Lee, J.T., D.L. Call, R.E. LAWSON, Jr., W.E. Clements, and D.E. Hoard. A video image analysis system for concentration measurements and flow visualization in building wakes. Presentation, Fourth International Workshop on Wind and Water Tunnel Modeling of Atmospheric Flows and Dispersion, Karlsruhe, West Germany, October 3-6, 1988. LA UR-88-4014, Los Alamos National Laboratory, 1988, Los Alamos, NM, 40 pp. (1989).

A video image analysis technique for concentration measurements and flow visualization was developed for the study of diffusion in building wakes and other wind tunnel flows. Smoke injected into the flow was photographed from above with a video camera, and the video signal was digitized in real time during the experiment and during playback with a video image analysis system. The relation between the digitized smoke intensity and the vertically integrated concentration of smoke particles was obtained from calibration experiments in which the smoke was replaced by a mixture of ethane and air. The time-averaged vertically-integrated concentration of the ethane tracer was measured at discrete points throughout the flow field and correlated with the time-averaged smoke intensity data. After the system was calibrated, the instantaneous and time-averaged fields of vertically integrated concentration were obtained by simply photographing the smoke plume. Color-contoured images of the plume were created and displayed in real time thus creating a pseudo-color movie that was very useful for flow visualization. This technique was used to study the effects of building geometry and source location on the concentration and flow patterns in building wakes.

AR-057

MACHTA, L. On the benefits of simultaneous measurements - an example. In Global Climate Change Linkages - Acid Rain, Air Quality, and Stratospheric Ozone, J.C. White (ed.). Elsevier Science Publishing Company, Inc., 213-217. (1989).

Extended abstract.

AR-058

MCMILLEN, R.T. Estimating the spatial variability of trace gas deposition velocities. NOAA TM ERL ARL-181 (PB90-208570), 37 pp. (1990).

Dry deposition of gaseous and particulate materials constitutes a significant fraction of the total acidic deposition. Dry deposition measurements are difficult to obtain and are usually available only for a single location. An understanding of the spatial variability of dry deposition is fundamental to extending site-specific measurements to subregional and regional scales. This study estimates the spatial variability of the dry deposition velocity over three 84 km by 84 km study areas by use of a deposition velocity model. Inputs to the model consist of meteorology, land use type, and terrain roughness. Meteorological data were derived from U.S. Geological Survey (USGS) Digital Elevation Models and Landsat Thematic Mapper data, respectively. Model run results are presented for one month's data at one site and for 12 weekly averages at all three sites. Verification of the technique is presented, but only at a single point.

AR-059

MEYERS, T.P., B.J. Huebert, and B.B. HICKS. HNO_3 deposition to a deciduous forest. Boundary-Layer Meteorology 49:395-410 (1989).

The deposition velocity (V_d) of nitric acid vapor over a fully leafed deciduous forest was estimated using flux/gradient theory. HNO_3 deposition velocities ranged from 2.2 to 6.0 cm/s with a mean V_d on the order of 4.0 cm s^{-1}. Estimates of V_d from a detailed canopy turbulence model gave deposition velocities of similar magnitude. The model was used to investigate the sensitivity of V_d to the leaf boundary-layer resistance and leaf area index (LAI). Although modeled deposition velocities were found to be sensitive to the parameterization of the leaf boundary-layer resistance, they were less sensitive to the LAI. Modeled V_d's were found to peak at LAI=7.

AR-060

Mikkelsen, T., A. Hansen, R.M. ECKMAN, and S. Thykier-Nielsen. Aerial smoke plume observations and surface layer turbulence measurements, Part I. Project WIND, Phase IV, Dispersion Study. Riso National Laboratory, Riso-M-2718 (1989).

No abstract.

AR-061

MILLER, J.M. (Editor). GAW and precipitation chemistry measurement activities. World Meteorological Organization Fact Sheet No. 5, Geneva, Switzerland (1989).

No abstract.

AR-062

Olsen, A.R., E.C. Voldner, D.S. Bigelow, W.H. Chan, T.L. CLARK, M.A. Lusis, P.K. Misra, and R.J. Vet. Unified wet deposition data summaries for North America: Data summary procedures and results for 1980-1986. Atmospheric Environment 24A:661-672 (1990).

This paper presents a framework for data quality assessment of annual and seasonal precipitation chemistry data summaries. Consideration has been given to (i) using data from regional or national networks with established quality assurance/quality control programs and well documented network operation protocols, (ii) assessing regional representativeness of each site, (iii) determining quantitative measures to define data completeness levels, and (iv) documenting the calculation procedures used to compute precipitation-weighted mean concentrations and wet deposition amounts. The procedures described here are applied to data collected from 1980 to 1986 by five major acid deposition monitoring networks in North America and examples of annual sulfate deposition summaries are reported. It is recommended that the concepts of site representativeness, data completeness and overall data quality levels be adopted by the user community and routinely be reported along with a data summary. Further work on assessing accuracy and precision to accompany the data quality levels is recommended.

AR-063

PARUNGO, F., C. NAGAMOTO, S. Hoyt, and H. Bravo A. The investigation of air quality and acid rain over the Gulf of Mexico. Atmospheric Environment 24A:109-123 (1990).

A research cruise was conducted in the summer of 1986 by a group of scientists from the U.S.A. and Mexico to investigate air chemistry over the Gulf of Mexico. Chemical, physical, meteorological and oceanographic measurements were carried out to survey temporal and spatial variations of diverse parameters throughout the Gulf. Emphases were placed on air-sea-land exchange of gases and

aerosols, natural air quality, transport of anthropogenic air pollution, and acid rain deposition to the Gulf. Although the prevailing winds were easterly from the sea during the cruise, the air was highly polluted with continental aerosols, probably caused by local shifting winds and the oscillation between sea breeze and land breeze. Aerosol number concentrations were measured from 10^5 cm^{-3} at ports to 10^3 cm^{-3} in the open Gulf. The average aerosol mass concentration was ~25 $\mu g\ M^{-3}$, consisting of 60% insoluble crustal particles that contained Si, Al, Fe; 30% seasalt particles that contained Na+ and Cl⁻; and 10% anthropogenic sulfate and nitrate particles. Samples of rain water collected near the coast were acidic (pH ~4). The concentrations of dimethyl sulfide correlated with bio-particle concentrations in surface seawater and could be a significant precursor of atmospheric SO_4^{2-} particles. The life cycles of the aerosols in the Gulf, including sources, transport, transformation, and wet and dry deposition are discussed.

AR-064

PARUNGO, F., C. NAGAMOTO, B. Kopcewicz, J. HARRIS, M.Y. Zhou, and N.P. Lu. Investigation of sulfate aerosols over the western Pacific Ocean. Proceedings, The International Conference on Global and Regional Environmental Atmospheric Chemistry, Beijing, China, May 1989. Conf-890525, National Technical Information Service, Springfield, VA, 168-178 (1990).

Two research cruises were conducted along the same track in the western Pacific Ocean to investigate temporal and geographic variations of sulfate aerosols. Backward air trajectories were computed for analyzing aerosol sources and transport. In the first cruise, during the fall 1987 El Niño anomaly, the westerly upper-level winds carried vast amounts of anthropogenic air pollution from Asia into the western Pacific. The enrichment factor (EF) of sulfate, compared with seawater, was 9.0 near the continent and gradually decreased to 1.1 in the palegic central Pacific. In the second cruise, spring 1988, when the normal easterly winds prevailed, the EF ranged from 3.5 to 1.2, with high EF only near the shore. Particle number concentrations also varied with time and location, ranging from 3000 to 100 cm^{-3}. Since sulfate particles are active cloud condensation nuclei, the variability may modify cloud drop size distributions and thus affect albedo, surface temperature, and precipitation.

AR-065

PARUNGO, F.P., C.T. NAGAMOTO, P.J. SHERIDAN, and R.C. Schnell. Aerosol characteristics of arctic haze sampled during AGASP-II. Atmospheric Environment 24A(4):937-949 (1990).

As part of the second Arctic Gas and Aerosol Sampling Program (AGASP-II), Arctic aerosol samples were collected by the NOAA WP-3D aircraft in spring 1986. The samples were analyzed in bulk and individual-particle form, using ion chromatography (IC) and electron microscopy (EM), respectively. Information on the chemical composition of the aerosol as determined by various techniques is presented, as well as morphology concentration, and size distribution data obtained from individual particle analyses. For most flights, a stratospheric sample and a haze profile sample were collected. Haze samples exhibited greater particle concentrations than stratospheric samples, the highest concentrations in haze reaching ~10^3 cm^{-3} (non-volatile particles >0.05 μm diam.). Sulfur was consistently observed to be a major element in both large and small particles in haze samples. Crustal elements such as Si, Al, K, Ca and Fe were often present in significant concentrations together with S. Particles that did not emit X-rays, possibly organic or sooty C, were observed in significant concentrations in both tropospheric and stratospheric samples. Chemical spot tests confirmed that SO_4^{2-} was the major S-containing species and that NO_3^- was not nearly as prevalent as SO_4^{2-} in the Arctic aerosol particles. The mass concentrations of major anions (Cl^-, SO_4^{2-} and NO_3^-) and cations (Na^+, K^+, NH_4^+, Ca^{2+} and Mg^{2+}) in the bulk aerosols were determined using IC. The ratios between ion concentrations, e.g. Ca^{2+}/Na^+, SO_4^{2-}/Na^+ and Cl^-/Na^+, may serve as indicators of aerosol origins and mixing status of various air masses. Aerosols collected on six flights demonstrated variability of particle characteristics in relation to sources and transport of Arctic haze.

AR-066

PERRY, S.G., and P.L. FINKELSTEIN. The U.S. Environmental Protection Agency's model for complex terrain applications. Proceedings, Tenth International Conference of the Clean Air Society of Australia and New Zealand, Auckland, New Zealand, March 25-30, 1990, 139-144 (1990).

The Complex Terrain Dispersion Model Plus Algorithms for Unstable Situations (CTDMPLUS), a point-source, steady-state, dispersion model for complex terrain applications, is described and its performance summarized. The mode is unique in the manner in which it simulates the flow and plume distortion near the terrain. Emphasis is given to windward side impacts. Simplicity is maintained by applying flow distortion corrections to flat-terrain, Gaussian and bi-Gaussian pollutant distributions. The performance of CTDMPLUS contrasts with that of a currently-recommended, complex-terrain, regulatory model. In stable or neutral conditions, CTDMPLUS shows relatively small average bias compared to field observations. The root- mean-square differences between CTDMPLUS and the observations are consistently lower and the percent of predictions within a factor of two are significantly higher than those of the regulatory model. In convective conditions, with comparisons unpaired in time or space, CTDMPLUS performs very well.

AR-067

PETERSEN, W.B., and A.H. HUBER. Concentration fluctuations of a toxic material downwind of a building. Proceedings, 1990 EPA/A&WMA International Symposium on Measurement of Toxic and Related Air Pollutants, Raleigh, NC, April 30 - May 4, 1990. U.S. Environmental Protection Agency, Research Triangle Park, NC, and Air & Waste Management Association, Pittsburgh (1990).

No abstract.

AR-068

PIERCE, T.E., B.K. Lamb, and A.R. Van Meter. Development of a biogenic emissions inventory system for regional scale air pollution models. Proceedings, 83rd Annual Meeting of the Air & Waste Management Association, Pittsburgh, PA, June 24-29, 1990. Air & Waste Management Association, Pittsburgh, 90-94.3 (1990).

No abstract.

AR-069

PIERCE, T.E., K.L. SCHERE, D.C. DOLL, and W.E. Heilman. Evaluation of the Regional Oxidant Model (Version 2.1) using ambient and diagnostic simulations. EPA/600/3-90/046, Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, NC, 105 pp. (1990).

This report discusses an evaluation of the latest version of EPA's Regional Oxidant Model, ROM2.1. In the ambient evaluation, model estimates were compared with ambient measurements of hourly surface ozone collected on 26 days during the summer of 1985 in the northeastern United States. Observed and modeled maximum daytime concentrations agreed, on average, to within 2 ppb or 1.4% (79 ppb versus 77 ppb). The model tended to underestimate at the higher extremes of the frequency distribution. The 95th-percentile value was underestimated by 8 ppb or 6.6% (127 ppb versus 119 ppb), and the overall maximum value was underestimated by 50 ppb or 22.7% (219 ppb versus 169 ppb). Underestimates at the upper percentiles tended to be more prevalent in the southern and western portions of the model domain. Concentrations at the lower end of the frequency distribution were slightly overestimated. Estimated and observed spatial patterns of three day maximum ozone generally showed good agreement. ROM2.1 improved noticeably over ROM2.0 with regard to the orientation of the high-ozone plumes in the Northeast Corridor and the depiction of high concentrations along the coast of Maine. Similar to ROM2.0, a tendency to underestimate peak concentrations near Washington, DC, was again evident with ROM2.1. A unique aspect of the ambient evaluation was an assessment of the model's ability to estimate boundary conditions for the Urban Airshed Model. Near the New York City Metropolitan Area, estimated and observed boundary conditions agreed to within 4 ppb or 7.6% (57 ppb versus 61 ppb). Model performance was degraded, however, during some situations with dynamic mesoscale wind flow conditions. ROM2.1 also underwent a series of diagnostic tests to investigate the accuracy of its numerical solution algorithms. When the model was subjected to extremely steep concentration gradients (steeper than those observed in the ambient atmosphere), the model did not conserve mass during a 48 h simulation, deviating by as much as 18% from the initialized value. With more realistic concentration gradient tests, however, the model conserved mass. ROM2.1 will be undergoing a series of improvements based largely on findings of this evaluation. The next version of the model will include refinement of vertical layer specifications and turbulence parameters, and a correction to the mass imbalance problem. Later versions of the model will likely include a dynamic meteorological processor that will simulate nonsteady-state flows.

AR-070

PITCHFORD, M.L., B.V. Polkowsky, M.R. McGown, W.C. Malm, J.V. Molenar, and L. Mauch. Percent change in extinction coefficient: A proposed approach for federal visibility protection strategy. Visibility and Fine Particles, C.V. Mathai (ed.), AWMA Transactions Series, No. 17, Air & Waste Management Association, Pittsburgh, 37-49 (1990).

This paper describes a regulatory strategy for protecting visibility from hazes(as opposed to elevated layers and plumes). The proposed strategy combines two features which have been mutually exclusive in previously considered strategies. It is simple (simple to state, to understand, and to apply) and it will provide an appropriate level of visibility protection regardless of the nature of the scene or present air quality conditions. The strategy would establish easily predictable control levels now and in the future. The strategy has two parts. The first part provides an approach for preventing additional noticeable visibility impairments while the second part provides a mechanism for gradually improving visual air quality to any predetermined levels (e.g., in Federal Class I areas the goal is Congressionally established at natural background levels). Perceptual arguments that support the nature and levels of proposed strategy are presented, including discussion of a series of scenic photographs with computer generated hazes that were shown during the presentation. Also presented is a discussion of the efforts that would be required to establish and implement such a strategy.

AR-071

Polkowsky, B.V., and M.L. PITCHFORD. Discussion of federal regulatory approaches for addressing regional visibility impairment. Visibility and Fine Particles, C.V. Mathai (ed.), AWMA Transactions Series, No. 17, Air & Waste Management Association, Pittsburgh, 29-36 (1990).

Over the past decade the U.S. Environmental Protection Agency (EPA), together with the Federal Land Managers and States have implemented a program for visibility protection in federal Class I areas. This program was set forth in regulations promulgated by EPA in 1980. The program is focused on "reasonably attributable" impairment cases and review of major new source impairments to Class I areas. At this time, it would be useful to review options available to EPA to address non-source specific visibility impairments in a regulatory manner. Regional haze regulatory approaches under the current Clear Air Act, and proposed revisions to that Act, range from a simple fine particle concentration regulation to a regulation based on changes in extinction levels in Class I areas. The ability of these regulatory frameworks to directly address visibility impairment and to work in conjunction with other regional effects programs varies greatly.

AR-072

POOLE-KOBER, E.M., and H.J. VIEBROCK. Fiscal year 1988 summary of NOAA Meteorology Division support to the U.S. Environmental Protection Agency. NOAA TM ERL ARL-180 (PB90-179896), 61 pp. (1989).

The Meteorology Division provided meteorological research and operational support to the U.S. Environmental Protection Agency. Basic meteorological operational support consisted of applying dispersion models and conducting dispersion studies and model evaluations. The primary research effort was the development and evaluation of air quality simulation models using numerical and physical techniques supported by field studies. Modeling emphasis was on the dispersion of photochemical oxidants and particulate matter on urban and regional scales, dispersion in complex terrain, and the transport, transformation, and deposition of acidic materials. Highlights during FY-1988 included applying the Regional Oxidant Model (ROM) to evaluate the effects of proposed strategies to control anthropogenic hydrocarbons and NO_x; implementing the ACID-MODES surface monitoring network and conducting an intensive ground and airborne sampling program to provide data for the evaluation of the Regional Acid Deposition Model (RADM); completing the Complex Terrain Dispersion Model (CTDM); completing the Acid Rain Mountain Mesoscale Model (ARM3); and conducting dense-gas dispersion studies in the Fluid Modeling Facility.

AR-073

POSSIEL, N.C., D.C. DOLL, K.A. Baugues, E.W. Baldridge, and R.A. Wayland. Impacts of regional control strategies on ozone in the northeastern United States. Proceedings, 83rd Annual Meeting of the Air & Waste Management Association, Pittsburgh, PA, June 24-29, 1990. Air & Waste Management Association, Pittsburgh, 90-93.3 (1990).

No abstract.

AR-074

POSSIEL, N.C., and T.E. PIERCE. Model-predicted ozone transport patterns in the northeast United States. Preprints, 18th International Technical Meeting of NATO-CCMS on Air Pollution Modelling and its Application, Volume 2, Vancouver, Canada, May 14-17, 1990. NATO/CCMS, Brussels, Belgium, 389-390 (1990).

No abstract.

AR-075

Raman, S., P. Boone, and K.S. RAO. Observations and numerical simulation of the evolution of the tropical planetary boundary layer during total solar eclipses. Atmospheric Environment 24A:789-799 (1990).

Two convective boundary layer experiments were conducted in the tropics during total solar eclipses, one at Raichur, India on 16 February 1980 and the other at Tanjung Kodok, Java, Indonesia on 11 June 1983. Period of totality was about 3 min at Raichur and 5 min at Java. With the partial phase of the eclipse extending over a combined period of about 2-h before and after totality, there was sufficient time in these experiments for the atmospheric boundary layer to react to changes in solar radiation. Results from the Indian experiment indicated significant changes in the atmospheric stability during the eclipse with slightly stable conditions present after the second contact. Java observations showed similar results but with smaller effects. Changes in stability also caused changes in turbulence structure. In this paper, we present the observations made during these two experiments, as well as the results of numerical simulations using a one-dimensional, second-order closure PBL model. In terms of location, the Raichur site with approximately homogenous conditions was better suited for the model simulations than Tanjung Kodok, which was located about 1 km downwind from the ocean.

AR-076

Rao, K.S., and J.M. GODOWITCH. The inclusion of pollutant removal processes in urban air quality models. Proceedings, 1990 EPA/AWMA International Symposium on Measurements of Toxic and Related Air Pollutants, Raleigh, NC, April 30 - May 4, 1990. U.S. Environmental Protection Agency, Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, NC, and Air & Waste Management Association, Pittsburgh (1990).

Gaseous and particulate pollutants emitted into the atmosphere are removed by several natural processes. Important among them are the dry deposition of pollutants at the earth's surface, and chemical transformation in the atmosphere. These removal mechanisms affect the pollutant concentrations and residence times in the atmosphere and therefore, it is necessary to account for them in air quality models, which are often used to assess the risk associated with chronic exposure of population to toxic air contaminants. This paper describes a methodology for including dry deposition and a first order chemical transformation in urban air pollution models based on the Gaussian diffusion framework. The concentration algorithms for point sources are derived from analytical solutions of a gradient transfer model. In the limit when deposition and settling velocities and the chemical transformation rate are zero, these expressions for various stability and mixing conditions reduce to the familiar Gaussian plume diffusion algorithms without the removal processes. The point source algorithms are integrated to obtain the concentrations due to emissions from distributed urban area sources. A new mathematical approach, based on mass budget considerations, is outlined to derive simple expressions for ground level concentrations. The concentration and deposition flux formulations described in this paper are currently used in several of EPA's air quality models.

AR-077

Rao, K.S., and M.A. Schaub. Observed variations of σ_θ and σ_ϕ in the nocturnal drainage flow in a deep valley. Boundary-Layer Meteorology 51:31-48 (1990).

The variations of σ_θ and σ_ϕ in the drainage flow in the Brush Creek valley of western Colorado are investigated using data form Doppler acoustic sodars and instrumented towers. The data were obtained in two experimental nights during the 1984 ASCOT field study. There is good agreement between the σ variations derived from low-level observations of the sodars and those derived from the towers located throughout the valley. The observed hourly average σ_θ and σ_ϕ in the nocturnal drainage flow are about 20° to 25° and 5°, respectively; these values are much larger than those generally observed over flat terrain during nighttime stable conditions. After sunrise (about 0600 MST), as the valley warms and the flow direction changes to up-valley, these parameters increase sharply to their peak values at about 0800 MST and then decrease to their normal daytime values after about two hours. In the drainage flow, the hourly average σ_θ varies inversely with wind speed according to the relation $\sigma\theta\bar{u} \approx 0.7 ms^{-1}$. The vertical standard deviation is much less enhanced by complex terrain than the horizontal standard deviation. The observed σ_ϕ values are predicted fairly well by the local similarity theory.

AR-078

Rao, S.T., G. Sistla, K. SCHERE, and J. GODOWITCH. Analysis of ozone air quality over the New York Metropolitan Area. Preprints, 18th International Technical Meeting of NATO-CCMS on Air Pollution Modelling and its Application, Volume 1, Vancouver, Canada, May 13-17, 1990. NATO/CCMS, Brussels, Belgium, 95-104 (1990).

No abstract.

AR-079

ROSELLE, S.J., and K.L. SCHERE. Sensitivity of the EPA Regional Oxidant Model to biogenic hydrocarbon emissions. Proceedings, 83rd Annual Meeting of the Air & Waste Management Association, Pittsburgh, PA, June 24-29, 1990. Air & Waste Management Association, Pittsburgh, 90-94 (1990).

No abstract.

AR-080

Rosinski, J., B. Kopcewicz, and N. SANDOVAL. Heterogeneous nucleation of ice at the liquid-liquid interface. Journal of Aerosol Science 21(1):87-96 (1990).

Aerosol particles containing liquid terpenes do not act as cloud condensation nuclei; they do not initiate formation of cloud droplets in clouds. They do, however, act as ice-forming nuclei initiating formation of ice particles. Presence of sulfate ions in cloud droplets appear to make them susceptible to freezing at higher temperatures when in contact with some of the terpenes. Heterogeneous nucleation of ice at a liquid-liquid interface was found to take place at higher temperatures in aqueous ammonium sulfate solutions than in pure water. The averaged temperatures of the phase transition were -3.6, -4.7, -4.4 and -4.8°C for pine needle oil, χ-pinene oxide, eucalyptol and linalool, respectively; the corresponding temperature increases were 4.7, 7.8, 3.6 and 6.7°C. Separation of terpene molecules by dilution in carbon tetrachloride produced a marked decrease in ice nucleation temperatures. It was suggested that the arrangements of dipoles at the interface have decisive influences on the phase transition. Temperature of ice nucleation in the presence of solutions of hexadecanol in carbon

tetrachloride generally decreases with a decrease of its concentration; the highest temperature of -5.0°C was found at 10^{-5} M of hexadecanol and 10^{-1} M of ammonium sulfate.

AR-081

Roswall, T. (Rapporteur), F. Bak, D. BALDOCCHI, R.J. Cicerone, R. Conrad, D.H. Ehhalt, M.K. Firestone, I.E. Galbally, V.F. Galchenko, P.M. Groffman, H. Papen, W.S. Reeburgh, and E. Sanhueza. What regulates production and consumption of trace gases in ecosystems: biology or physicochemistry? In Exchange of Trace Gases between Terrestrial Ecosystems and the Atmosphere, M.O. Andreae and D.S. Schimel (eds.). John Wiley & Sons Ltd., Chichester, 73-95 (1990).

No abstract.

AR-082

Roth, P.M., C.L. Blanchard, S.D. Reynolds, and R.L. DENNIS. The role of grid-based, reactive air quality modeling in policy analysis: Perspectives and implications, as drawn from a case study. Preprints, 18th International Technical Meeting of NATO-CCMS on Air Pollution Modelling and its Application, Volume 1, Vancouver, Canada, May 13-17, 1990. NATO/CCMS, Brussels, Belgium, 197-206 (1990).

No abstract.

AR-083

Sievering, H., C. Crouch, L. GUNTER, D. WELLMAN, and J. BOATMAN. Determination of elemental concentrations in small-mass particulate matter aircraft samples by x-ray fluorescence. Atmospheric Environment 23(9):2059-2062 (1989).

Aircraft sampling of atmospheric particulate matter often implies small mass collection for subsequent analysis, especially when free tropospheric samples are considered. We present here results of the use of an X-ray fluorescence instrument, specifically designed for small-mass samples, in the determination of free tropospheric and boundary layer elemental concentrations. Based on 1- to 2-h-long samples, ng m^{-3} ambient air concentrations of Ti, Cr, Mn, Ni, Cu, Zn, As, Se, Br, Rb, Sr, Y, Zr, Mo, Cd and Pb may be determined with uncertainties of 5-15% in polluted and even some rural boundary layer samples. In free tropospheric and remote boundary layer samples, concentrations may be determined for many of these elements but with larger uncertainties.

AR-084

Sievering, H., P.J. SHERIDAN, and R.C. Schnell. Size distribution of large aerosol particles during AGASP-II: Absence of St. Augustine eruptive particles in the Alaskan Arctic. Atmospheric Environment 23(11):2495-2499 (1989).

Number distribution data for 0.1-45 μm diameter aerosol were obtained using optical counting and sizing probes flown over the Alaskan Arctic during the second Arctic Gas and Aerosol Sampling Program (AGASP-II), flights 201-203. Due to noise present in the lowest size channels of the optical probes, estimates of the H_2SO_4 component of Arctic haze were not attempted. Large particle (>0.5 μm diameter) results are presented here. Large particle number and volume concentration were determined along with estimated mass, which was generally ≤0.1 μg m^{-3}. Lognormal fitting to >0.3 μg m^{-3} mass loading size-distributed aerosol date produced a means for comparing volume geometric median diameters (VGMD) for these higher-mass time intervals. These VGMDs showed that solid crustal particles previously observed during AGASP-II had VGMDs in the 1.2-1.6 μm range and that the shape of these fitted lognormal distributions were essentially constant. This result suggests very-long-range transport from a distant crustal source and, in conjunction with aerosol physical and chemical characterization data, argues against the presence of the Mt. Augustine eruptive particle's during AGASP-II Alaskan Arctic sampling.

AR-085

SNYDER, W.H. Book Review. Stably Stratified Flow and Dense Gas Dispersion. (J.S. Puttock (Ed.), Clarendon Press, 1988.) Bulletin of the American Meteorological Society 71:730-731 (1990).

No abstract.

AR-086

SNYDER, W.H. Fluid modeling applied to atmospheric diffusion in complex terrain. Atmospheric Environment 24A:2071-2088 (1990).

Wind-tunnel and towing-tank studies conducted over the past 10 years at the U.S. Environmental Protection Agency's Fluid Modeling Facility (FMF) of flow and diffusion in complex terrain are reviewed. A primary impetus for this work was EPA's Complex Terrain Model Development Program (CTMDP) -- designed to develop reliable atmospheric dispersion models applicable to large pollutant sources in complex terrain, with primary emphasis on plume impaction during nighttime stable conditions. The FMF interacted closely with the model developers participating in the CTMDP and provided support in various ways through the conduct of a wide range of laboratory studies. Work at the FMF prior to the inception of the program provided the basic framework for the model -- the dividing-streamline concept -- and the focal point around which the field program was designed. At the beginning of the program, the FMF provided direct support as an aid to planning the details and strategies of the field experiments and testing the limits of applicability of the dividing-streamline concept. Later work included exercises of "filling in the gaps" in the field data, furthering the understanding of the physical mechanisms important to plume impaction in complex terrain and in stably stratified flows in general, testing various modeling assumptions, providing data for "calibration" of various modeling parameters, and testing the ability of the laboratory models to simulate full-scale conditions. Simultaneously, the FMF responded to the needs of the regulatory arm of EPA, the Office of Air Quality Planning and Standards (OAQPS), by providing guidance concerning expected terrain effects and by conducting demonstration studies. These latter studies were concerned primarily with simulation of diffusion in the neutral atmospheric boundary layer. Finally, several supplemental studies were conducted, broadening and expanding upon the specific requests of the model developers and the OAQPS. The highlights of the FMF complex-terrain research work are described herein.

AR-087

Stewart, J.W.B. (Rapporteur), I. Aselmann, A.F. Bouwman, R.L. Desjardins, B.B. HICKS, P.A. Matson, H. Rodhe, D.S. Schimel, B.H. Svensson, R. Wassmann, M.J. Whiticar, and W.-X. Yang. Extrapolation of flux measurements to regional and global scales. In Exchange of Trace Gases between Terrestrial Ecosystems and the Atmosphere, M.O. Andreae and D.S. Schimel (eds.). John Wiley & Sons Ltd., Chichester, 155-174 (1990).

No abstract.

AR-088

STUNDER, B.J.B., R.S. ARTZ, G.D. ROLPH, J.F. BOATMAN, R.L. GUNTER, J.M. HARRIS, and J.T. Merrill. Meteorological conditions over the North Atlantic Ocean during GCE/CASE/WATOX. NOAA TM ERL ARL-183 (PB90-252032), 82 pp. (+ Appendices) (1990).

During the summer of 1988, a team of scientists aboard the NOAA ship Mt. Mitchell and the NOAA King Air aircraft investigated the spatial distributions of sulfur, nitrogen, and related species and their interactions during transport from North America. In support of these measurements, meteorological data from the National Meteorological Center and from rawinsonde data obtained from the ship were archived and back-trajectories were calculated. A summary of the meteorological conditions during the cruise is presented using synoptic maps, soundings, cross-sections and isobaric and isentropic back-trajectories. Since day-to-day variability of the synoptic situation was usually small, one representative day from each meteorological regime was chosen to illustrate the overall meteorology. During the cruise, three synoptic regimes were encountered: (1) north of the polar front, (2) the Bermuda/Azores High, and (3) the Intertropical Convergence Zone (ITCZ). Sounding data and derived parameters from three different days illustrate these regimes. Boundary layer depth and cloud layers were also estimated from all the soundings. Cross-sections of temperature and wind, potential temperature, relative humidity, mixing ratio, and air fluxes describing the vertical structure of the atmosphere along the cruise show the general day-to-day uniformity except near the polar front and at the ITCZ boundary. The back-trajectories show general air flow patterns and the land mass source regions of air reaching the ship within three days. For parts of the cruise, air reached the ship from North America, Iceland or Greenland, Africa, and South America.

AR-089

STUNDER, B.J.B., and R.R. DRAXLER. Across North America Tracer Experiment (ANATEX) Volume II: Aircraft-based sampling. NOAA TM ERL ARL-177 (PB90-14548), 29 pp. (1989).

Aircraft-based sampling was an integral part of ANATEX. The data are useful for establishing the initial tracer path and for providing vertical tracer distributions. Because there were few, if any, ground-level sampling sites near the sources, the aircraft sampling was done within about 450 km of the two release sites (Glasgow, MT and St. Cloud, MN) and between altitudes near the ground to 2800 m above ground. One or two aircraft sampled 26 of the 33 Glasgow plumes. Usually one flew above the other to obtain vertical tracer profiles. The GGW plume was traversed at least once for 23 of the 26 releases sampled, with 30% of all the samples near GGW containing excess tracer. One aircraft sampled 16 St. Cloud plumes, with tracer concentrations above background reported for all 16 releases. Fifty percent of all the samples of the STC plume contained excess tracer. The instrumentation, operations, and data quality assurance are discussed. The complete archived dataset, consisting of aircraft position data, tracer data, and meteorological data, is included in the report. In addition, data summaries for all flights are displayed in a tabular format.

AR-090

Tangirala, R.S., K.S. RAO, and R.P. HOSKER, JR. Puff model simulation of surface concentration data from tracer releases in the nocturnal drainage flow in a deep valley. Preprints, Fifth Conference on Mountain Meteorology, Boulder, CO, June 25-29, 1990. American Meteorological Society, Boston, 296-300 (1990).

No abstract.

AR-091

Tans, P.P., K.W. Thoning, W.P. ELLIOTT, and T.J. CONWAY. Error estimates of background atmospheric CO_2 patterns from weekly flask samples. Journal of Geophysical Research 95(D9):14,063-14,070 (1990).

The precision and accuracy of trends and seasonal cycles of CO_2, as determined from grab samples, was investigated. First, the statistical aspects of infrequent (weekly) sampling were studied by simulating, via a partially random procedure, parallel time series of CO_2 flask samples. These simulated flask series were compared to the continuous analyzer records from which they had been derived. The second approach to studying the uncertainties of flask records was to compare real flask results with simultaneous hourly mean concentrations of the in situ analyzers at the Geophysical Monitoring for Climatic Change observatories at Point Barrow, Mauna Loa, Samoa, and the South Pole. The latter comparisons emphasized experimental, rather than statistical, errors. The uncertainties and sampling biases depend on the site and on the period of averaging. For monthly means the uncertainty varies from 0.2 to 0.6 ppm (one standard deviation, parts per million by volume), being largest for Barrow. Sampling biases for monthly means at Barrow and Mauna Loa are significant, up to 0.5 ppm. Experimental errors are the dominant error source for annual averages, and spurious interannual variations can be up to 0.4 ppm.

AR-092

van Dop, H., F.A. SCHIERMEIER, M.L. Williams, A. Venkatram, and A. Ebel. Report on Meeting: 17th International Technical Meeting of NATO-CCMS on Air Pollution Modelling and Its Application. Atmospheric Environment 23:1428-1432 (1989).

No abstract.

AR-093

VAN VALIN, C.C., M. Luria, J.D. Ray, and J.F. BOATMAN. Hydrogen peroxide and ozone over the northeastern United States in June 1987. Journal of Geophysical Research 95(D5):5689-5695 (1990).

Continuous measurements of ozone (O_3) and hydrogen peroxide (H_2O_2), and of other trace gases and meteorological parameters were made using the NOAA King Air research aircraft. The atmosphere was sampled at various elevations from minimum altitude above ground level up to 4 km above sea level, over the northeastern United States between Columbus, Ohio, and Saranac Lake, New York, during June 1987. The average O_3 concentrations, calculated for constant-altitude flight segments, are in the range 50-110 ppbv; the H_2O_2 range for the same flight segments is 0.6-3.6 ppbv. Concentration profiles of O_3 show little variation with altitude, with the exception of samples taken in polluted areas. The highest H_2O_2 concentrations are observed at the lowest altitudes in air from southern regions, i.e., in air containing the greatest water vapor density. The concentrations of both O_3 and H_2O_2 show a clear decrease from lower (40°N) to higher (44°N) sampling latitudes.

AR-094

Vukovich, F.M., and J.K.S. CHING. Semi-empirical approach to estimate vertical transport by nonprecipitating convective clouds on a regional scale. Atmospheric Environment 24:2153-2168 (1990).

A semi-empirical approach to estimate the vertical flux of mass between the boundary layer and the cloud layer by an ensemble of nonprecipitating cumulus clouds has been developed. The model determines the existence of the cloud ensemble, estimates the cloud amount at cloud base, and establishes the vertical distribution of the convective cloud amount attributed to a cloud population having a continuous spectrum of cloud depth, using standard meteorological data. The mass flux is then estimated for the ensemble or for a "processor" cloud, a single cloud which, on the average, can be used to represent the ensemble using a modified version of the cloud model developed by Ritter and Stedman (1985, Coop. Agreement No. CR 807485-01,02). Results of a sensitivity analysis are presented. The analysis examined the behavior of the model as the vertical distribution of temperature and dew point changed from one atmospheric state to another.

AR-095

WELLMAN, D.L., M. Luria, C.C. VAN VALIN, and J.F. BOATMAN. The use of an airborne air sampling platform for regional air quality studies. NOAA TR ERL 437-ARL 10 (PB90-107145/XSP), 15 pp. (1989).

A Beechcraft King Air, owned and operated by the Office of Aircraft Operations, National Oceanic and Atmospheric Administration (NOAA), was converted from a passenger airplane into an atmospheric air quality sampling platform. It has been used in several regional air quality studies including the Gulf Coast Experiment, the Western Atlantic Ocean Experiment (WATOX), and the Processing of Emissions by Clouds and Precipitation (PRECP) experiment. The aircraft is equipped to measure atmospheric trace gases (SO_2, O_3, and NO_x), aerosols, and meteorological parameters (temperature, humidity, wind speed, wind direction, atmospheric pressure, and solar radiation). It has grab sampling equipment (for aerosol chemistry and organic compounds) and instruments for continuously recording position and heading. Most of the scientific equipment aboard was provided by the Air Quality Group, Air Resources Laboratory, NOAA, with additional support from several universities and other institutions. The WATOX project is used as an example to demonstrate the capabilities of the aircraft as a regional air quality sampling platform. During this experiment, air samples were taken in the winter and spring seasons of 1985 and 1986 at two locations off the U.S. East Coast (Newport News, VA, and Boston, MA) and in the vicinity of Bermuda. These locations were selected to provide samples representative of contaminated air masses exiting from the continent and being transported over the Atlantic Ocean. Flight tracks were designed to assess the flux of atmospheric pollutants above and within the planetary boundary layer. Through the successful use of the aircraft, it was revealed that most of the pollutant transport within this region was being accomplished inside the boundary layer. Additionally, in several cases, contaminated air masses were observed in the free troposphere.

AR-096

Yamada, T., J.M. Leone, Jr., K.S. RAO, M.H. Dickerson, D.C. Bader, and M.D. Williams. Applications of complex terrain meteorological models to emergency response management. Preprints, 2nd International Workshop on Real-Time Computing of the Environmental Consequences of an Accidental Release to the Atmosphere from a Nuclear Installation, Luxembourg, May 15-19, 1989. Commission of European Communities, Brussels, (1990).

The Office of Health and Environmental Research (OHER), U.S. Department of Energy (DOE), has supported the development of mesoscale transport and diffusion and meteorological models for several decades. The model development activities are closely tied to the OHER field measurement program which has generated a large amount of meteorological and tracer gas data that have been used extensively to test and improve both meteorological and dispersion models. This paper briefly discusses the history of the model development activities associated with the OHER atmospheric science program. The discussion will then focus on how results from this program have made their way into the emergency response community in the past and what activities are presently being pursued to improve real-time emergency response capabilities. Finally, fruitful areas of research for improving real-time emergency response modeling capabilities are suggested.

AR-097

Zhou, M.Y., S.J. Yang, F.P. PARUNGO, and J.M. HARRIS. Chemistry of marine aerosols over the western Pacific Ocean. Journal of Geophysical Research 95:1779-1787 (1990).

During the first cruise operated by the United States of America and the People's Republic of China cooperative program, from December 12, 1985, to February 21, 1986, aerosol samples were collected with a KA-200 Anderson cascade impactor and a KB-120 sampler. Neutron activation analysis was used to determine the elemental composition of the aerosols. Maximum mass concentrations of sea-salt elements (Na, Cl, and Br) were found in the size range 3.3-4.7 μm. The "bulk" enrichment factor for Cl in aerosols, relative to Na in seawater, was close to unity, but a very pronounced depletion was found for Br. The enrichment factor for Cl in different size ranges decreased with increasing particle size and for Br had a U-shaped curve. The size distributions for Fe, Al, and Sc over the remote ocean and over the ocean area close to the Asian continent were quite different. Aerosols over the western Pacific showed significant enrichment of Sb and Se, relative to Fe. Some characteristics of marine aerosols are discussed as they relate to long-range transport of crustal elements and pollution elements from the Asian continent to the western Pacific.

Addendum

AR-098

Battye, W., J. Langstaff, M. Smith, N.C. POSSIEL, E.L. Meyer, Jr., and K. Baugues. Regional ozone modeling for northeast transport -- development of a base year emissions inventory. Proceedings, 82nd Annual Meeting of the Air and Waste Management Association, Anaheim, California, June 25-30, 1989. Air & Waste Management Association, Pittsburgh, 89-3.8 (1989).

No abstract.

AR-099

NAPPO, C.J. A theoretical investigation of gravity-wave-generated stress and vorticity in the planetary boundary layer. Ph.D. dissertation, Georgia Institute of Technology, Atlanta, 176 pp. (1989).

Vertically propagating gravity waves are generated whenever a stable atmospheric flow passes over a terrain obstacle of sufficiently large horizontal size. These waves act to propagate mean-flow horizontal momentum to the ground surface. This downward flux of momentum represents a Reynolds stress, but this stress can only act on the atmosphere if the gravity waves are absorbed by the mean flow. Wave absorption will occur near a critical level where the phase speed of the wave equals the component of the background flow parallel to the wave vector. For the case of terrain-generated waves, critical levels will exist where the component of the background flow directed over the obstacle reverses its direction. Within the planetary boundary layer (PBL) over regions of complex terrain, wind reversals frequently occur. Thus we expect that wave stresses will have an effect on the PBL dynamics. However, conventional PBL theory does not account for gravity-wave stress, and so it is important to evaluate the magnitude of the wave stress relative to the friction stress. Using simple linear wave theory, the wave stresses and wave drags over two-dimensional ridges and three-dimensional hills are evaluated for typical stable PBL conditions. We find, for example, that the magnitude of the wave stress over ridges and hills is comparable to the friction stress, and that the drag over a given crosswind section of a two-dimensional ridge is about twice as great as that over a three-dimensional hill of approximately the same horizontal area. We expect that the wave stress over a ridge will generate a layer of turbulence near the critical level; also, we show that flow blocking and nonlinear wave behavior can also lead to wave absorption and induced turbulence above two-dimensional ridges. We demonstrate that over a three-dimensional hill, the wave stresses act to generate a horizontal layer of counter-rotating vortices near a critical level. The intensity of these vortices is predicted to increase linearly with time. Typically, a few minutes after wave absorption begins the magnitude of the vorticity exceeds that generated by the Earth's rotation. The vertical wind shears across the critical level increase with time until the flow becomes unstable. When this happens, an isolated patch of turbulence and enhanced lateral dispersion will exist above the hill. Such layers have been observed in the PBL.

AR-100

PARUNGO, F., and J. MILLER. Air chemistry studies over the Gulf of Mexico. NOAA TM ERL ESG-29 (PB88-179239/GAR), 254 pp. (1988).

This report documents the scientific research of a bilateral cooperative project between the United States of America and the United States of Mexico. In 1986 scientists from both nations joined a research cruise in the Gulf of Mexico to investigate the air chemistry over the water that the two nations share. Emphases were placed on natural air quality, anthropogenic air pollution, acid rain, air-sea-land exchanges of gases and aerosols. The investigation included in-situ measurements and post-cruise laboratory analyses. Chemical, physical, meteorological, and oceanographic analyses were conducted to survey temporal and spatial variations of diverse parameters throughout the Gulf. The data sets were analyzed, interpreted, and intercorrelated. The results show that during the cruise (20 July-22 August), the large-scale air trajectories were easterly from the Caribbean Sea at all levels; however, the Gulf air measured was highly polluted in general. This is probably due to the oscillation of land breeze and sea breeze, and local shifting winds that brought continental air masses into the Gulf. The aerosol mass concentrations ranged from 5 to 78 with an average of 25 $\mu g/m^3$, and the number concentrations ranged from 5×10^2 to 10^5 with an average $2 \times 10^3/cm^3$. The maxima were found near the ports and petroleum refineries; the minima were in the open sea where the concentrations were still an order of magnitude greater than measurement over the South Pacific Ocean. Concentrations of gases (O_3, CO_2, CH_4, H_2S and total hydrocarbons) generally followed a similar distribution pattern except gases decreased more rapidly than aerosols when moving away from the sources. The life cycle of dimethyl sulfide (DMS) produced by marine biotic processes was studied. Its measured concentrations in seawater ranged from 22 to 244 with an average of 130 ng/L. The maximum concentrations were found in Campeche Bay where the highest concentrations of biomass in surface seawater were measured. The anticyclonic gyres observed in the western Gulf might cause upwelling of nutrient-rich deep-sea water to support bio-activities. The total sea-to-air flux of DMS in the Gulf was calculated as 2.3×10^9 g S each day or 0.84 Tg per year. However, the concentrations of DMS in the atmosphere were <20 ng/m^3. The result suggests that DMS has a very short lifetime (≤ 1.6 h) in the Gulf air. It is probably oxidized rapidly and converted to other sulfur gases or aerosols. The Gulf water is also a vast sink for atmospheric aerosols and gases. The dry deposition flux of aerosols was estimated at ~ 120 Tg/yr including 60% of water-insoluble particles containing Si, Al, Fe, etc., and 40% of water-soluble salts containing Na^+, Cl^-, $SO_4^=$, NO_3^-, Mg^{++}, Ca^{++}, K^+, etc. The anthropogenic sulfate and nitrate particles, in addition to seasalt particles, are active cloud condensation nuclei and thus have the potential to increase cloud coverage and precipitation. The rain samples collected near ports were mostly acidic (pH, 4 to 5). The major ion concentrations were $Cl^- > Na^+ > SO_4^= > NO_3^-$. Approximately 80% of the $SO_4^=$ and NO_3^- in the rain were incorporated through the aerosol phase, either by condensation nucleation at cloud base or by below-cloud scavenging; only <20% were incorporated through in-cloud adsorption of precursor gases followed by liquid-phase oxidation. (The mechanisms are different from polluted continental precipitation in which in-cloud gas-phase incorporation was observed to be more important.) Based on the data set of rainwater chemistry and the annual precipitation rate in the region (~ 110 cm), wet deposition of atmospheric aerosols was estimated to be much more important than dry deposition to the Gulf.

AR-101

Paw U, K.T., and T.P. MEYERS. Investigations with a higher-order canopy turbulence model into mean source-sink levels and bulk canopy resistances. Agricultural and Forest Meteorology 47:259-271 (1989).

The legitimacy of using bulk aerodynamic and canopy resistances in surface energy budget equations is examined in this paper. Specifically, the variation of the effective source heights for momentum, water vapor, and heat is analyzed by estimating zero plane displacements for a modeled soya bean canopy, when model leaf surface resistances are changed, causing varying stability conditions. Also, the changes in bulk canopy resistances are examined as a function of the leaf surface resistances. The model used is a linked soil-plant-atmosphere model based on higher-order closure principles. The model confirms previous reports of major soil contributions to evapotranspiration under certain conditions. The erratic behavior of the zero plane displacements for water vapor and heat as a function of leaf surface resistance demonstrates that the concept of a single effective source-sink height is not easily applied to plant canopies. The zero plane displacement for momentum was found to be consistent with previous results, independent of leaf surface resistance. Canopy resistance changes qualitatively match leaf surface resistance changes, but quantitative differences can be large. The canopy resistance changes less quickly than the leaf surface resistance even when soil evaporation is not a factor.

AR-102

Porch, W.M., S. Barr, W.E. Clements, J.A. Archuleta, A.B. Fernandez, C.W. King, W.D. Neff, and R.P. HOSKER. Smoke flow visualization in a tributary of a deep valley. Bulletin of the American Meteorological Society 70:30-35 (1989).

Smoke pot and oil fog smoke tracers have been used to plan meteorological instrument placement and quantitatively estimate air volume flow from a tributary during nocturnal drainage wind conditions. The estimated volume flow agrees well with estimates of the flow using tethered balloon and remote wind velocity measurements. The smoke visualization shows a very complex flow structure caused by tributary flow interactions with the flow down the main valley. The magnitude of the outflow volume from the tributary was greater than expected. if the tributary studied is representative of the other tributaries in the valley, most of the volume flow in the main valley may enter through the tributaries.

ATLANTIC OCEANOGRAPHIC AND METEOROLOGICAL LABORATORY

AO-001

Baik, J.-J., M. DEMARIA, and S. Ramen. Tropical cyclone simulations with the Betts convective adjustment scheme. Part I: Model description and control simulation. Monthly Weather Review 118(3):513-528 (1990).

A new convective parameterization scheme proposed by Betts is tested in a tropical cyclone model. The convective adjustment scheme adjusts the local temperature and moisture structures towards the observed quasi-equilibrium thermodynamic state and includes nonprecipitating shallow convection as well as deep convection. The numerical model used for this study is an axisymmetric, primitive equation, hydrostatic, finite difference model with 15 vertical levels and a horizontal resolution of 20 km. The spectral radiation boundary condition, which uses a different gravity wave speed for each vertical mode, is implemented in the model. It is shown that the convective scheme is capable of simulating the developing, rapidly intensifying, and mature stages of a tropical cyclone from a weak vortex. At the mature stage, the minimum surface pressure and maximum low-level tangential wind speed are around 932 mb and 58 m s^{-1}. During the early developing stage, the latent heat release is from the convective parameterization, but at the mature stage the latent heat release is mainly due to the grid-scale phase change. For comparison, an experiment is conducted with the parameterized convection excluded, leaving only the grid-scale condensation and evaporation. The results show that the development of a tropical cyclone can be modeled with crude grid-scale condensation and evaporation processes for the 20 km horizontal resolution, similar to other studies. However, the storm with the explicit convective latent heat release is considerably less intense than that with the parameterized convective latent heat release.

AO-002

Baik, J.-J., M. DEMARIA, and S. Ramen. Tropical cyclone simulations with the Betts convective adjustment scheme. Part II: Sensitivity experiments. Monthly Weather Review 118(3):529-541 (1990).

Extensive sensitivity experiments with an axisymmetric tropical cyclone model that includes the Betts convective parameterization scheme are carried out. The sensitivity of the model storm evolution to the convective adjustment parameters is studied. These results show that the model storm leads to earlier development as the adjustment time scale becomes small and the stability weight on the moist adiabat in the lower atmosphere is increased. The model storm evolution is very sensitive to variations in the saturation pressure departure at the lowermost model integer level and the storm at mature stage has a lower central pressure as the magnitude of the saturation pressure departure is increased. The adjustment parameters affect the grid-scale precipitation as well as the convective precipitation, and the precipitation is especially sensitive to changes in the saturation pressure departure. Sensitivity of the model to variations in the sea surface temperature, latitude, initial vortex amplitude, initial moisture distribution, and radiation is also investigated. The results of the numerical simulations are similar to previous studies. Sensitivity studies with various horizontal resolutions show that the subgrid-scale heating becomes a larger fraction of the total heating as the horizontal grid size is increased.

AO-003

BITTERMAN, D.S., P.P. Niiler, Y. Aoustin, and A. du Chaffaut. Drift buoy intercomparison test results. NOAA DR ERL AOML-17 (NTIS number not yet available), 52 pp. (1990).

Detailed tests were carried out aboard the NOAA ship OCEANOGRAPHER to measure the slippage of several drift buoy designs used in the TOGA Pan Pacific Surface Current Study. These included the AOML low-cost tropical drifter, the Scripps Institution of Oceanography Ministar drifter, the MIT Draper Laboratory low-cost drifter, and the IFREMER (Brest, France) thermistor chain buoy. The results of six tests carried out under varying wind and sea conditions are included.

AO-004

BLACK, R.A. Radar reflectivity - ice water content relationships for use above the melting level in hurricanes. Journal of Applied Meteorology 29(9):955-961 (1990).

Regression equations linking radar reflectivity (Z_e) and ice water content (IWC) were calculated from airborne radar and particle image data that were collected above the melting level in two hurricanes. The Z_e-IWC equation from the stratiform areas of Hurricane Norbert (1984) is similar to the composite equation for thunderstorm anvils derived by Heymsfield and Palmer. The Z_e-IWC equation from the convective regions of Hurricane Irene (1981) has essentially the same exponent, but a significantly greater coefficient than that from Norbert. The higher density of the graupel and rounded ice in the Irene data accounts for the difference in the coefficients. The hurricane Z_e-IWC relations have

smaller exponents than most of those from midlatitude clouds, which indicates that small ice particles may be more prevalent in these two hurricanes than in midlatitude clouds.

AO-005

BLACK, R.A., and J. Hallett. Electric field and microphysical measurements in vigorous hurricane eyewalls. Preprints, Conference on Cloud Physics, San Francisco, CA, July 23-27, 1990. American Meteorological Society, Boston, 662-665 (1990).

No abstract.

AO-006

BURPEE, R.W. Gordon E. Dunn: Preeminent forecaster of midlatitude storms and tropical cyclones. Weather and Forecasting 4(4):573-584 (1989).

No abstract.

AO-007

BURPEE, R.W., and M.L. BLACK. Temporal and spatial variations near the centers of two tropical cyclones. Monthly Weather Review 117(10):2204-2218 (1989).

The Hurricane Research Division collected radar reflectivity data with a portable recorder that was attached to the WSR-57 radar at National Weather Service offices as Hurricane Alicia of 1983 and Elena of 1985 approached the U.S. coastline. The reflectivity data were used to compute rain rates for the eyewall region, including the rain-free eye and the rainbands in the annular area outside the eyewall, but within 75 km of the center of the eye. Area- and time-averaged rain rates (R) in the eyewall region were 5.2 and 6.0 mm h^{-1}, respectively, for Alicia and Elena. The corresponding averages in the rainband region were 2.8 and 3.4 mm h^{-1}. The rain rates include reflectivity corrections that were based upon the variation of average returned power with range in four hurricanes. Precipitation was convective in the eyewall region and largely stratiform in the rainband region. Comparison with published results from other tropical cyclones suggests that the corrected R's in the eyewall region are underestimated, but are within a factor of 1.6 of the actual amount. The R's in the rainband region, however, are similar to those from other studies. Alicia's eyewall region represented 15% of the computational area and contributed 25% of the total rain rate within 75 km of the center of the eye. Elena's eyewall region comprised 22% of the area and contributed 33% of the area-averaged rain rate. The area-averaged rain rate (R) in the eyewall region of both hurricanes varied by up to 4 mm in 1-2 h. In Alicia, the variations of R were caused by the growth and decay of mesoscale convective areas with reflectivity > 38 dBZ that achieved maximum areas of 500-800 km^2. In Elena, life cycles of individual convective cells with maximum reflectivities > 48 dBZ also accounted for large changes in the eyewall R. In both hurricanes, the time series of R in the rainband regions were less variable than the eyewall R because the rainband regions included larger areas than the eyewall and had a smaller percentage of area with convective activity. For several hours, the maximum rain rates in the eyewall and rainband regions of Alicia occurred in the left-front quadrant relative to the storm motion. Then the maximum rain rate in the eyewall region shifted to the right-front quadrant and the maximum in the rainband region moved to the right of the storm track. In Elena, the maximum rain rates in the eyewall and rainband regions were in the right-front quadrant throughout the computational period. About 55% of the precipitation in Elena's eyewall region occurred in the right-front quadrant. In both hurricanes, the maximum rain rate in the rainband region was generally oriented to the right of that in the eyewall region.

AO-008

Carey, A.G., Jr., G.L. Taghon, D.L. Stein, and P.A. RONA. Distributional ecology of selected benthic megaepifauna and fishes in the Gorda Ridge axial valley. In Gorda Ridge: A Seafloor Spreading Center in the United States' Exclusive Economic Zone, G.R. McMurray (ed.). Springer-Verlag, New York, 225-240 (1990).

Using bottom photographs and videotapes taken by various institutions in 1984 to 1986, we describe the taxonomic composition and patterns of distribution on two geographic scales and the relative abundance of the benthic epifauna and fishes in Gorda Ridge axial valley. Gorda Ridge runs approximately northeast-southwest 200 to 300 km off northern California and southern Oregon and lies within the U.S. Exclusive Economic Zone. Suspension feeding invertebrate taxa occur in all rocky and sedimentary environments. Crinoids appear dominant at the northernmost stations, and ascidians are dominant in the central Gorda Ridge region. In the sedimented Escanaba Trough hexactinellid sponges and gorgonian soft corals are present. Suspension feeding epifauna tend to occur nonrandomly with even distributions predominant. Assemblages of invertebrates and fishes associated with rock and sediment differ in composition and abundance. Deposit feeding organisms become relatively more abundant and are interspersed with stalked suspension feeders at the southern

stations of the sediment-filled southern Escanaba Trough. Many species associated with sediments are similar to those found on the surrounding abyssal plains. Biomass is unevenly distributed. The axial valley fauna is abundant and diverse, undoubtedly supported by organic materials of continental origin, including run-off from the Columbia River. In addition, scattered hydrothermal venting provides energy sources for adjacent chemosynthesis-based food webs. The enclosing valley walls and rough topography appear to constrain currents and cause turbulence that maintains the high concentrations of suspended particles observed near the valley floor.

AO-009

Clague, D.A., and P.A. RONA. Geology of the GR14 site on the northern Gorda Ridge. In Gorda Ridge: A Sea-floor Spreading Center in the United States' Exclusive Economic Zone, G.R. McMurray (ed.). Springer-Verlag, New York, 31-50 (1990).

The northern Gorda Ridge is spreading at an intermediate rate but exhibits a deep, well-defined rift valley and petrologic diversity more like the slow-spreading Mid-Atlantic Ridge than other oceanic ridges with intermediate rates of spreading. A detailed investigation of a 10 km by 10 km area of the floor and eastern wall of the rift valley was conducted in order to define the geologic setting of active high-temperature hydrothermal vents regionally located using water column studies. High temperature vents are apparently located on the east wall of the rift valley at the southern end of a linear ridge at a location where ridge-parallel and anomalous ridge-oblique tectonic trends intersect. Additional hydrothermal deposits were discovered along the axis of the valley floor near the shoal point of the axial valley of the northern Gorda Ridge, adjacent to an area of sheet flows. These deposits are of the two types: a massive material, probably nontronite, and white coatings on talus that consist of mixed layer clay and boehmite. These axial deposits do not appear to be actively forming. This study suggests that past and present hydrothermal activity occurs near the shallowest and volcanically most productive segment of the ridge, and the locations of the vents are controlled by the intersection of tectonic trends.

AO-010

DEMARIA, M. Normal-mode initialization in a tropical cyclone model. Journal of the Atmospheric Sciences 118(9):2199-2214 (1990).

The effect of nonlinear normal mode initialization (NMI) on tropical cyclone simulations is investigated using a three-layer axisymmetric model. It is shown that the balance condition proposed by Machenhauer, which neglects the time tendencies of the gravity mode amplitudes, is valid in a tropical cyclone simulation. The boundary layer friction and adiabatic nonlinear and diabatic heating terms are all important in the balance. A highly truncated version of the model with linearized physical parameterizations is used to analyze the convergence properties of several iterative schemes developed to solve the initialization equations. When diabatic heating is neglected, the schemes will converge if the linear friction coefficient a is smaller than the Coriolis parameter f. For small horizontal-scale modes, the iterative schemes will converge for values of a much larger than f. When diabatic heating is included, the rate of convergence of the small horizontal-scale modes becomes extremely slow. The schemes are also tested in the nonlinear version of the model by first running a 7-day tropical cyclone simulation. The initialization schemes are applied at day 5 after the model has produced an intense tropical cyclone. Results show that the tropical cyclone rapidly weakens relative to the uninitialized run during the 6-12 h after the NMI is applied. This weakening occurs because the small horizontal-scale modes do not converge, making the secondary radial circulation much too weak. A scheme is proposed where the NMI is followed by a short integration with the geostrophic modes held fixed. This procedure compensates for the lack of convergence of the small horizontal-scale gravity modes.

AO-011

DEMARIA, M., and R.W. JONES. The use of aircraft observations in a hurricane track forecast model. Preprints, International Symposium on Assimilation of Observations in Meteorology and Oceanography, Clermont-Ferrand, France, July 9-13, 1990. American Meteorological Society, Boston, 191-195 (1990).

No abstract.

AO-012

DEMARIA, M., M.B. Lawrence, and J.T. Kroll. An error analysis of Atlantic tropical cyclone track guidance models. Weather and Forecasting 5(1):47-61 (1990).

Mean track forecast errors over the 6-year period 1983-1988 are compared for four tropical cyclone track forecast models in use at the National Hurricane Center. The model types represented are: statistical, statistical-dynamical, barotropic-dynamical and baroclinic-dynamical. The statistical-dynamical model (NHC83) had the smallest mean errors

at all forecast periods between 12 and 72 h while the baroclinic-dynamical model (MFM) had the largest errors at 12 and 24 h. NHC83 was the only model which had statistically significant forecast skill relative to the CLIPER model. When the forecasts were stratified by latitude, the MFM had significant skill at 36 and 48 h for the northern storms. Further analysis of the forecast errors shows that most of the models have a bias towards the southwest. The MFM has a very large westward bias for low-latitude storms, which results from a fast speed bias in that region. NHC83 has relatively small speed and directional biases, while CLIPER and SANBAR have slow biases. The MFM has been replaced (beginning in 1988) by a new baroclinic-dynamical model (the Quasi-Lagrangian Model, QLM). A comparison of the MFM and QLM for the 1988 season shows that the QLM has error characteristics similar to the MFM. A barotropic-dynamical model is used to give some insight into the behavior of dynamical track prediction models. Results show that initial position errors have a negligible effect on the average track forecast errors, except at 12 h. Errors in the estimate of the initial storm motion affect the forecast errors out to 72 h. Several spatial filters are applied to the initial analyses, which shows that the model storm track is the most sensitive to very large scales (3,000-6,000 km wavelengths).

AO-013

DODGE, P.P., J.S. GRIFFIN, F.D. MARKS, JR., and R.W. BURPEE. Interactive analysis of NOAA P-3 aircraft data in support of operational hurricane forecasting. Preprints, Sixth International Conference on Interactive Information and Processing Systems for Meteorology, Oceanography and Hydrology, Anaheim, CA, February 4-9, 1990. American Meteorological Society, Boston, 245-247 (1990).

No abstract.

AO-014

FRANKLIN, J.L., C.S. Velden, J. KAPLAN, and C.M. Hayden. Some comparisons of VAS and dropwindsonde data over the subtropical Atlantic. Monthly Weather Review 118(9):1869-1887 (1990).

Omega dropwindsonde and other in-situ (INS) data collected during the NOAA/Hurricane Research Division's (HRD) Field Program are used as a ground truth dataset for the evaluation of VISSR Atmospheric Sounder (VAS) soundings over the subtropical Atlantic. The experiments were coordinated with the Cooperative Institute for Meteorological Satellite Services at the University of Wisconsin. The focus of this study is to determine whether soundings derived from VAS radiances are an improvement over the first-guess data used as a starting point in the sounding retrieval process. First-guess inputs for this study are provided by NMC's Regional Analysis and Forecast System (RAFS) nested-grid model (NGM). In a case study, an objective algorithm is used to analyze the INS, VAS, and first-guess data at and below 500 mb from an HRD experiment on 1-2 September 1988. The case study is supplemented by a statistical investigation of data composited from other HRD experiments. In particular, we examine VAS estimates of horizontal temperature and moisture gradients to see if they represent improvements over the first guess. The temperature and moisture descriptions in the vicinity of a 500 mb cold low were improved by the VAS in the case study; however, VAS temperature gradients were found to be generally less accurate than those of the first guess. Temperature gradients from the VAS were also consistently stronger than INS or first-guess gradients. The composite study found that large-scale VAS moisture gradients were better than those of the first guess. Other results indicate a preferred mode for VAS modifications to the guess; the primary impact of the VAS radiances on the first guess was to improve the description of the phasing of horizontal features. The VAS representation of the amplitude of features, however, was not consistently an improvement. This suggests that in tropical applications, VAS data may be most suitable for subjective forecasting uses; if VAS data are to be used in numerical weather prediction, strongest weight should be given to the representation of the location of weather features (troughs, ridges, etc.), and relatively weak weight should be given to the representation of the strength of these features.

AO-015

GAMACHE, J.F. Microphysical observations in summer MONEX convective and stratiform clouds. Monthly Weather Review 118(6):1238-1249 (1990).

Two-dimensional images of ice particles observed by a NOAA WP-3D research aircraft during the Summer Monsoon Experiment (SMONEX) are examined. These images were obtained in the temperature interval from -25° to 0°C. The particle structures and size distributions found in convective and stratiform clouds are compared. Branched crystals were located predominantly in stratiform clouds while column-shaped crystals were located commonly in both stratiform and convective clouds. Stratiform clouds, particularly those observed at temperatures warmer than -7°C, had a much greater percentage concentration of large ice particles (> 0.8 mm in diameter), and many of these ice particles were aggregates or branched crystals. The importance of aggregation and deposition above the melting level in stratiform clouds is strongly suggested by these findings. Ice particle number concentrations measured with the cloud probe were often very high in convective clouds, with a maximum value of approximately 800 L^{-1}. The average convective-cloud concentration was approximately 230 L^{-1}, while the average concentration in the stratiform clouds was approximately 20 L^{-1}. Liquid water

was almost completely absent in the convective updrafts, at temperatures between -10° and -22°C. This suggests that the convective updrafts may have been nearly completely glaciated, and the microphysics were dominated by deposition. The high particle concentrations in the convective updrafts suggest that the updrafts may provide most of the ice particles found in the stratiform cloud. Significant modification in particle structures and size distributions has occurred, however, by the time these suspended particles fall out of the stratiform clouds. These modifications appear to arise from aggregation and deposition.

AO-016

Georges, T.M., and D.R. PALMER. Applications of ocean acoustic remote sensing to climate monitoring. TM ERL WPL-185 (NTIS number not yet available), 9 pp. (1990).

No abstract.

AO-017

Hallett, J., and P.T. WILLIS. Development of precipitation in isolated maritime cumulus. Preprints, Conference on Cloud Physics, San Francisco, CA, July 23-27, 1990. American Meteorological Society, Boston, 74-79 (1990).

No abstract.

AO-018

HANSEN, D.V., and A. HERMAN. Evolution of isotherm depth anomalies in the eastern tropical Pacific Ocean during the El Niño event of 1982-83. Journal of Geophysical Research 94(C10):14,461-14,473 (1989).

Subsurface temperature data collected from research vessels, aircraft, and vessels of opportunity are used to describe the evolution of the major El Niño event in the tropical Pacific from September 1982 through September 1983. Optimum interpolation is used to create six analysis maps of the anomalous depths of the 20°C, 15°C, and 10°C isothermal surfaces. The region analyzed is 20°N to 20°S and 140°W to the coast of the Americas. Each analysis is based on data accumulated over about a month, and the analysis periods are separated by about a month. The depths of the 20°C isotherm are used to compute zonal thermoclinic transports across 100°W of the North and South Equatorial Currents and the North Equatorial Countercurrent.

AO-019

HANSON, K., G.W. Brier, and G.A. MAUL. Evidence of significant nonrandom behavior in the recurrence of strong El Niños between 1525-1988. Geophysical Research Letters 16(10):1181-1184 (1989).

The precise character of the quasiperiodic variation in the recurrence of El Niño events has been unclear. To gain insight into the nature of this apparent regularity, a 464-year record (1525-1988) of the initiation of "strong" El Niño events, derived from the chronology of Quinn et al. (1987), has been analyzed with a two-dimensional extension of the periodogram analysis method of Buys Ballot. The method is useful for detecting joint nonlinear interactions between variations at two specified periods. Results indicate joint nonrandom recurrence of strong El Niño events at periods of 6.75 and 14.0 years. From Monte Carlo tests, we estimate the statistical significance of this result to be at the 0.1% level. Alternating ~95 year-long time-blocks, where 6.75-year and 14.0-year recurrence periods dominate, is apparent from the analysis. No specific mechanism is offered for the periodic forcing of strong El Niño events, but our observation of significant quasi-periodic behavior in the initiation of such events at the combined periods of 6.75 and 14.0 years may be a clue in efforts to understand and model natural ENSO recurrence.

AO-020

Houde, E.D., P.B. ORTNER, L. Lubbers, III, and S.R. CUMMINGS. Test of a camera-net system to determine abundance and heterogeneity in anchovy egg distributions. Rapports et Proces-Verbaux des Reunions Cons. Int. Explor. Mer. 191:112-118 (1989).

A prototype, in situ camera-net system was deployed in Chesapeake Bay to test its ability to estimate abundances and delineate fine-scale vertical and horizontal distributions of bay anchovy Anchoa mitchilli eggs and larvae. Hydrographic variables were measured synoptically by electronic sensors on the system. Comparison catch data were obtained by simultaneous deployment of a conventional plankton net. The camera subsampled 1.9% of the water that entered the system and photographed part of the catch at 2-m intervals along the tow. Densities of anchovy eggs, which averaged 99.0 m^{-3} during six trial tows, were estimated at 1, 5, and 10 m depths. Anchovy larvae were uncommon (0.34 m^{-3}) and not sampled effectively. The system detected increasing egg abundances between the surface and 10 m depth and horizontal

patchiness over 10-100 m distances. In the configuration used, the system has potential where mean egg or larval densities exceed ca. 5 m^{-3}. Its advantages are that it can (1) reduce the need to collect and sort plankton samples, (2) provide photographic data for image analysis, and (3) synoptically assess fine-scale distributions of ichthyoplankton, environmental variables, and co-occurring predators and prey.

AO-021

Houze, R.A., Jr., B.F. Smull, and P.P. DODGE. Mesoscale organization of springtime rainstorms in Oklahoma. Monthly Weather Review 118(3):613-654 (1990).

Radar reflectivity and rain gage data obtained during six springtimes indicates the types of mesoscale organization that occur in association with major rain events in Oklahoma (at least 25 mm of rain in 24 h over an area exceeding 12,500 km^2). In these storms, the primary rain area is found to be a contiguous region of precipitation tens to hundreds of kilometers in scale that consists partly of deep convection and partly of stratiform rain. The patterns of rain formed by the convective and stratiform areas comprise a continuous spectrum of mesoscale structures. About two-thirds of the cases examined exhibited variations on the type of organization in which convective cells arranged in a moving line are followed by a region of stratiform rain. Storm organization was graded according to the degree to which it matched an idealized model of this "leading-line/trailing-stratiform" structure. The precipitation pattern was further graded according to whether its structure was relatively symmetric with respect to an axis normal to and passing through the midpoint of the line, or asymmetric, in which case the storm was biased toward having stronger, more discrete convective structure at the upwind (south or southwestern) end of the line and/or the most extensive stratiform precipitation behind the downwind (north to northeastern) end of the line. About one-third of the cases examined displayed much more chaotic, unclassifiable arrangements of convective and stratiform areas. Among the cases with leading-line/trailing-stratiform structure, severe weather was most frequent in systems with (i) a strong degree of leading-line/trailing-stratiform structure, in which a solid, relatively uniform, arc-shaped line had stratiform rain centered symmetrically behind it, and (ii) a weaker degree of leading-line/trailing-stratiform structure in which a southwest-northeast line was biased toward having narrow, intensely convective, irregularly spaced cell structure at its southwestern (upwind) end and stratiform rain confined to the region behind the broader northeastern (downwind) portion of the line. Although all mesoscale organization types were characterized by all types of severe weather, the type (ii) cases were the most prolific category in terms of tornado and hail production, while type (i) cases were prone to be associated with flooding. The chaotic, unclassifiable cases, which exhibited no line organization, had just as much severe weather as the cases with line organization, but were more likely to produce hail and somewhat less likely to produce tornadoes and flooding than the systems with line structure. Major rain events occurred whenever a mesoscale convective complex (MCC) was dissipating or merely skirting the area. However, 75% of the major rain events occurred under cloud shields that failed to meet the MCC criteria explicitly, although they often resembled MCC's qualitatively. No particular type of mesoscale radar-echo organization was favored when cloud shields meeting the MCC criteria were observed. A slight preference for the more chaotic type of organization was suggested; however, the data sample is not large enough for this finding to be regarded as conclusive. Mean soundings and hodographs generally show no sign of a low-level jet in environments associated with chaotically arranged rain areas that lacked any line structure. On the other hand, a low-level jet and resulting curved hodograph were typically associated with cases in which line organization was evident. The wind shear in the low-to-midtroposphere, the bulk Richardson number and other familiar parameters characterizing squall line environments are consistent with results from recent modeling studies. When leading-line/trailing-stratiform structure was present, the cross-line shear in the environment was of a magnitude associated with model simulations in which a rearward sloping updraft circulation favorable to trailing-stratiform anvil formation quickly develops. The along-line component of shear was greater when the squall system structure was of the asymmetric type and the degree of leading-line/trailing-stratiform structure was not as strong, i.e., in those mesoscale systems favoring tornado occurrence.

AO-022

Lalou, C., G. Thompson, M. Arnold, E. Bricher, E. Druffel, and P.A. RONA. Geochronology of TAG and Snakepit hydrothermal fields, Mid-Atlantic Ridge: Witness to a long and complex hydrothermal history. Earth and Planetary Science Letters 97:113-128 (1990).

Geochronological studies of a large number of precipitates from the TAG hydrothermal field and a few samples from the Snakepit hydrothermal field of the Mid-Atlantic Ridge show intermittent repeated hydrothermal events at both sites. $^{210}Pb/:b$ and $^{230}Th/^{234}U$ measurements of sulfides, iron and manganese oxides, and ^{14}C measurements of carbonates combined with observations of hydrothermal events recorded as discrete layers in sediment cores provide the basis for unraveling the temporal history of the fields. The TAG field shows intermittent activity over the past 120,000 years as evidenced by ages of low-temperature Mn oxides. The presently active black smoker mound first formed about 40,000-50,000 years ago with precipitation of massive sulfides. It has had intermittent, pulsed high-temperature activity every 5,000-6,000 years over the past 20,000 years which may reflect renewed magmatic activity at the ridge axis. Fluid flow is focused at the mound site by structural and tectonic control suggested by the intersection of north-south ridge parallel lystric normal faults and an east-west transform fault. Periods of inactivity are marked by covering of the mound with

pelagic carbonate ooze which is probably partially dissolved and reprecipitated as aragonite at the end of each high-temperature event. The Snakepit field had an initial event about 4,000 years ago, probably shortly after the eruption of the volcanic ridge on which it sits. A recent renewal, still presently active, was probably initiated by recent fissuring of the volcanic pile.

AO-023

Lord, S.J., and J.L. FRANKLIN. The environment of Hurricane Debby (1982). Part II: Thermodynamic fields. Monthly Weather Review 118(7):1444-1459 (1990).

A three-dimensional analysis of temperature and relative humidity in the environment of Hurricane Debby (1982) has been completed. Observations from Omega dropwindsondes (ODWs) within 1000 km of the storm have been combined with rawinsondes over the continental United States and the Caribbean and with observations from surface ships and aircraft data where possible. The temperature and relative humidity analyses, together with wind analyses from a previous study, form a dataset that can be used as an initial condition in a multilevel prognostic model when combined with analyses over areas larger than our analysis domain. In this paper a series of diagnostic tests has been applied to the dataset to evaluate its performance without using a prognostic model. These tests include horizontal maps of the moist convective instability, calculation of the heat and moisture budgets in the vicinity of Bermuda, which was 350 km to the northeast of the storm center, and diagnosis of precipitation from these budgets and from the Arakawa-Schubert cumulus parameterization. Results show that the horizontal distribution of moist convective instability is strongly affected by the low-level moisture field upstream of the main inflow region to the storm. The total surface heat flux, estimated with a bulk aerodynamic method, matches the vertically integrated eddy flux of moist static energy to within observational errors. Precipitation estimates from the budgets give rates of approximately 20 mm day^{-1}, which are consistent with an estimated rate from radar. Partition of the rainfall rate into convective scale and resolvable scale (stratiform) shows about equal contributions. Our results lead us to believe that, within the limitations determined by the horizontal distribution of the observations, the final data set for Hurricane Debby provides a realistic depiction of the various physical processes that were occurring in Debby's environment. Future work will include data sensitivity experiments with a three-dimensional forecast model.

AO-024

MARKS, F.D., JR., and P.G. BLACK. Close encounter with an intense mesoscale vortex within Hurricane Hugo (September 15, 1989). Extended Abstracts, 4th Conference on Mesoscale Processes, Boulder, CO, June 25-29, 1990. American Meteorological Society, Boston, 114-115 (1990).

No abstract.

AO-025

MAUL, G.A., and N.J. BRAVO. Fate of satellite-tracked buoys and drift cards off the southeastern Atlantic coast of the United States. Florida Scientist 52(3):154-170 (1989).

Twelve satellite-tracked drifting buoys were released, one each month between April 1984 and March 1985, at the 75 m isobath, 70 km southeast of Cape Canaveral, Florida. Starting in May 1984, 500 drift cards were also released at each buoy deployment from the same site (28°N, 80°W). In addition, satellite-tracked buoys from May 1979, September 1983, and February 1985, which drifted into or through the area, were studied for information about surface currents and particle trajectories. All 12 buoys from the 28°N/80°W launch site drifted north past Cape Canaveral (28.5°N); only the May 1984 buoy drifted into the coastal zone off Mayport, Florida (30.4°N), although several others showed a tendency to do so in that area. Every buoy deployed within 5 km of the western edge of the Gulf Stream was entrained into the current, and some as far as 25 km were also entrained. The September 1983 buoy, which was deployed slightly west of 28°N/80°W, and the February 1985 buoy, which was deployed in the Gulf of Mexico, both came ashore near St. Lucie Inlet, Florida (27.2°N), 140 km south of Cape Canaveral. Drift cards from May, September, October, and November 1984, and February 1985 were recovered west and north of 28°N/80°W. Forty percent of the cards recovered were from south of Cape Canaveral; Cocoa Beach, Florida (28.3°N), and Pontevedra Beach, Florida (30.2°N) reported most of the returns. For those months when drift cards were returned, buoy trajectories showed little correlation with drift card vectors. Drift cards established the possibility of materials coming ashore along the Florida Atlantic coast, both north and south of Cape Canaveral, particularly in the autumn.

AO-026

MAUL, G.A., D.A. MAYER, and M. BUSHNELL. Statistical relationships between local sea level and weather with Florida-Bahamas cable and Pegasus measurements of Florida Current volume transport. Journal of Geophysical Research 95(C3):3287-3296 (1990).

Straits of Florida sea level is studied as a measure of Florida Current volume transport because sea level provides an independent time series both (1) for detecting changes in the calibration of the Florida-Bahamas submarine cable which has been operating since 1982, and (2) as a measure of the strength of the Gulf Stream system dating to the 1930's when cable measurements were not available. Accordingly, tide gauge records from Haulover Beach (Miami) and Lake Worth, Florida, and from Cat Cay and Settlement Point, The Bahamas, together with Miami weather and cable voltage, are correlated with each other and with discrete volume transport estimated from all Pegasus data taken during the intensive 1982-84 Subtropical Atlantic Climate Studies (STACS) observations. Time domain linear correlation coefficients between these 132 Pegasus values and cable voltage observations, Cat Cay minus Haulover Beach sea level, and Haulover Beach sea level only, are 0.91, 0.55, and -0.76, respectively, but for the 1982-88 time series, Cat Cay minus Haulover Beach is better correlated with cable observations (0.62) than is Haulover Beach alone (-0.44). Frequency domain modeling computations reveal that the sea level and cable data are organized in such a way that most of their energy lies below frequencies of 30^{-1} cycles per day (cpd). In a subseasonal band (up to and including the semiannual frequency) 49% of the cable energy and 59% of the Haulover Beach energy can be accounted for using 30-day, low-passed data. A subseasonal frequency response function has been tentatively identified that relates both Florida sea level and Bahamas-Florida sea level difference to cable observations and can successfully account for more than 60% of the observed cable variance (standard error is 1×10^6 m^3 s^{-1}). Further, negative Florida sea level only and Bahamas-Florida sea level difference have different phase relationships with cable observations; it is suggested that steric effects could be responsible for the phase shifts.

AO-027

MAUL, G.A., J.R. PRONI, M. BUSHNELL, and J.L. Mitchell. Oceanic dynamic height anomaly from GEOSAT: A conceptual model for short collinear orbit segments. Marine Geodesy 12:259-285 (1989).

A method is derived for extracting oceanic dynamic height anomaly from collinear (exact repeat mission) GEOSAT short (1,000 km long) orbit segments. The procedure requires at least one year of simultaneous in-situ observations and involves: (1) computing with respect to the ellipsoid, a mean sea surface height (SSH) profile solely from altimetry; (2) linear least-squares removal of tilt and bias from individual SSH profiles with respect to the mean profile; (3) determining an independent mean dynamic height anomaly profile from hydrographic data along the orbit segment; (4) demeaning the tilt-and-bias removed individual SSH profiles and addition of the mean in-situ dynamic height anomaly; and (5) correcting for concurrently observed dynamic height anomaly at two or more suborbital points during satellite transit. Analysis of the concept suggests root sum squared errors of ± 5 cm, which can be reduced by smoothing and longer term measurements along the same orbit segment. A one-year comparison between two orbit segments at an open ocean crossover point shows differences of ± 2 cm, and comparison with six months of simultaneous in-situ data shows corrections of ±3 cm are required. Space-time plots of demeaned tilt-and-bias removed GEOSAT SSH profiles, compared with similarly processed NMC/CAC numerical circulation model calculations, show good agreement with variability in the South Equatorial Current/North Equatorial Countercurrent system in the eastern Pacific Ocean, and suggest that further development of the concept is warranted.

AO-028

MAYER, D.A., R.L. MOLINARI, and R.H. Weisberg. Analysis of volunteer observing ship temperature fields in the tropical Atlantic Ocean. Oceanologica Acta 13(3):257-264 (1990).

Volunteer observing ship SST data collected during the FGGE year in 1979 and data from in-situ moorings deployed during the SEQUAL/FOCAL experiment in 1983-1984 are used to estimate the dominant temporal and spatial scales of SST variability in the equatorial Atlantic Ocean. Two-dimensional Fourier transforms show that enhanced energy levels in a wave number and frequency band of 1924^{-1}-825^{-1} cycles/km and 37^{-1}-21^{-1} cycles/day, respectively, are associated with organized SST structures with wave-like oscillations that are consistent with barotropic instabilities. The oscillations appear on the equator between 1°S and 1°N eastward of 25°W shortly after the springtime intensification of the easterly wind stress and persist into August. They are characterized by a westward phase propagation of about -50 cm/s and a pattern that progresses eastward at approximately 30 cm/s.

AO-029

MILLER, K.L., and P.A. RONA. Bathymetric comparison of three mid-ocean ridge areas with slow-spreading characteristics. NOAA, National Undersea Research Program, Technical Report 89-3, 41 pp. (1989).

The Trans-Atlantic Geotraverse (TAG) and adjacent sections of the Mid-Atlantic Ridge (MAR), the French-American Mid-Ocean Undersea Study (FAMOUS) area of the MAR, and the northern and central Gorda Ridge all possess slow-spreading characteristics, although not all have slow-spreading rates (half-rate $\leq$ 2 cm/yr). Because spreading rate is not the only factor controlling mid-ocean ridge morphology, the three ridge sections were compared to

determine what similarities and differences exist between them. Similarities and differences were observed in morphologic character, valley shape, and valley symmetry of these three areas. Two hydrothermal fields located within the study areas, the TAG hydrothermal field and the newly discovered Sea Cliff hydrothermal field, were also compared to determine if a particular geologic setting is common to both hydrothermal fields. This comparison considered placement of the hydrothermal fields along the ridge segment, rift valley morphology, shape, and valley symmetry.

AO-030

PALMER, D.R. Book review, "Elastic wave propagation," North-Holland Series in Applied Mathematics and Mechanics, Vol. 35, M.F. McCarthy and M.A. Hayes (eds.). Journal of the Acoustical Society of America 88:1665 (1990).

No abstract.

AO-031

PALMER, D.R., T.M. Georges, and R.M. Jones. Chaos in underwater acoustics. Proceedings, Fifth International Symposium on Acoustic Remote Sensing of the Atmosphere and Oceans, S.P. Singal (ed.). New Delhi, India, February 6-9, 1990, Tata McGraw-Hill, 210-215 (1990).

During numerical simulations of acoustic propagation in a weakly range-dependent, deterministic ocean, we find conditions that produce chaotic ray paths. Chaos is an instability which results from the nonlinear nature of the differential equations which determine the ray paths, rather than from externally imposed noise or randomness. It places a fundamental limitation on the range to which an acoustic field can be predicted. We also discuss some new methods for identifying chaotic rays which have advantages over the standard methods. Finally, we note the existence of chaotic rays for propagation in the Straits of Florida.

AO-032

PALMER, D.R., T.M. Georges, and R.M. Jones. Classical chaos and the sensitivity of the acoustic field to small-scale ocean structure. Proceedings, First International Conference on Computational Physics, Boulder, CO, June 11-15, 1990, North Holland, 8-15 (1990).

Ray theory is usually the basis of data inversion schemes for acoustic remote sensing of the ocean. Chaotic ray paths are expected to be present whenever the ocean environment possesses small-scale, range-dependent structure. We are studying the implications of their presence for data inversion schemes. Using numerical simulations we consider ray-path characteristics for acoustic remote sensing of the Florida Current. We find small-scale bathymetric structure results in chaotic ray paths and an exponential proliferation of eigenrays. As a result, for each feature in the time-of-arrival pattern, there is associated not a single eigenray but a group, thereby limiting the spatial resolution of a remote sensing system.

AO-033

PALMER, D.R., and P.A. RONA. Comment on "Acoustic Doppler current profiler observations of a mid-ocean ridge hydrothermal plume." Journal of Geophysical Research 95(C4):5409-5412 (1990).

No Abstract.

AO-034

POWELL, M.D. Boundary layer structure and dynamics in outer hurricane rainbands. Part I: Mesoscale rainfall and kinematic structure. Monthly Weather Review 118(4):891-917 (1990).

Results of hurricane boundary layer experiments conducted in outer rainbands of Hurricanes Josephine (1984) and Earl (1986) are presented. Comparisons of precipitation and kinematic structures in these storms and in Hurricane Floyd (1981) indicate that principal rainbands have common characteristic mesoscale and convective-scale features in the boundary layer. The two-dimensional mesoscale structure suggests that these rainbands are made up of a linear aggregate of cellular reflectivity elements (on the inner, upshear side of the band) and stratiform rain (on the outer downshear side). The bands are oriented perpendicular to the shear above the boundary layer and cells move downband at about 85% of the density-weighted mean wind speed of the 0.2-6 km layer. The boundary layer windfield is strongly influenced by the rainband with alongband and crossband wind maxima located on the outer side of the band axis, and minima 4-8 km to the inner side. Maximum crossband convergence and cyclonic shear vorticity are also found to the inner side of the rainband axis. Updrafts and downdrafts are preferentially located on the inner side of the band axis, with some

downdrafts spreading out at the surface. The band-relative positions of the updraft and perturbation pressure minimum suggest that the minimum may be produced by interaction of the wind shear and the updraft. Outer hurricane rainbands show many similarities to tropical squall lines; major differences are associated with propagation and the structure of the leading and trailing edges.

AO-035

POWELL, M.D. Boundary layer structure and dynamics in outer hurricane rainbands. Part II: Downdraft modification and mixed-layer recovery. Monthly Weather Review 118(4):918-938 (1990).

Recent aircraft boundary layer measurements in the vicinity of principal hurricane rainbands have confirmed that convective downdrafts are capable of transporting cool, dry, low equivalent potential temperature (θ_E) air to the surface, where the mixed layer is eliminated. The incorporation of this air into convection near the core of the storm may weaken the storm, depending upon the scale of the disturbance and the processes governing the recovery of the air while it is flowing toward the eyewall. This paper examines the thermodynamic characteristics of the boundary layer in outer convective hurricane rainbands, providing evidence for downdraft modification mechanisms and determining the extent to which disturbed boundary layer air may be restored on its trajectory to the storm.

AO-036

POWELL, M.D. Meteorological aspects of Hurricane Hugo. Hugo, One Year Later, A Symposium and Public Forum, Charleston, SC, September 13-15, 1990. American Society of Civil Engineers (1990).

No abstract.

AO-037

POWELL, M.D. Observations of boundary layer structure and mesoscale wind fields in a midlatitude marine rainband during GALE. Extended Abstracts, 4th Conference on Mesoscale Processes, Boulder, CO, June 25-29, 1990. American Meteorological Society, Boston, 55-56 (1990).

No abstract.

AO-038

PRONI, J.R. Some acoustical observations of internal waves and associated turbulence in the coastal ocean. Journal of the Acoustical Society of America 87:S26 (1990).

Outstanding features of the coastal ocean influencing the acoustical study of internal waves and turbulence include the large quantities of suspended particulates present therein and the regularity, both in characteristics and occurrence, of internal wave groups. The coastal ocean is often occupied by internal wave groups possessing a well-known and consistent structure, namely a set of amplitude ordered solitons followed by a sequence of quasi-linear waves. Acoustical observations made using backscattered 20 kHz pulses of two events, conjectured to be internal wave group generated mixing and resuspension events, will be presented. The first event occurs at the interface separating Hudson-Raritan water from continental shelf water; the second event occurs in the oceanic bottom boundary layer. A third event generated by an oceanic discharge of material event wherein simultaneous generation of internal waves, turbulence and a mid-water column "turbidity" particulate surge will also be presented. Some implications for acoustical signal interpretation of temperature or salinity turbulent scattering events in the presence of a particulate distribution will be examined with specific emphasis on the implications for "calibration" of acoustical scattering instruments and the utility of acoustical devices for studying the decay of turbulent events.

AO-039

PRONI, J.R., W.P. DAMMANN, J.F. CRAYNOCK, and R. Fergen. Oceanic wastewater plume characteristics measured acoustically. Program and Abstracts, Eighth International Ocean Disposal Symposium, Dubrovnik, Yugoslavia, October 9-13, 1989. Inter-University Centre of Postgraduate Studies, 18-19 (1989).

The measurement of oceanic wastewater plume features is complex and the obtaining of samples of plume material is difficult. A study, called SEFLOE, has been conducted on wastewater outfalls off the coast of southeast Florida (USA). The wastewater plume field $F(r,0,z,t)$ is considered to be comprised of a set of subfields $f_i(r,0,z,t)$, i.e., $F(r,0,z,t) = F(f_1,\ldots,f_i,\ldots,f_n)$; likewise, the oceanic water column field $W(r,0,z,t)$, into which the wastewater plume is injected, is considered to be comprised of a set of subfields; i.e., $W(r,0,z,t) = W(W_1,\ldots,w_i,\ldots,w_n)$. In this study, the feasibility of utilizing high-frequency acoustics to provide an estimator field $I(r,0,z,t)$ for one or more of the wastewater plume sub-

fields $f_i(r,0,z,t)$ is examined. It is hypothesized that the water-column background corrected acoustical backscattered intensity $I(r,0,z,t)$ where $I(r,0,z,t) = \langle I_f(r,0,z,t)\rangle - \langle I_w(r,0,z,t)\rangle$ may be used to guide chemical/biological sampling and the physical structure of at least one wastewater plume subfield is revealed by the structure of $I(r,0,z,t)$ (the brackets denote a measured quantity). Data from SEFLOE have indicated that the wastewater plume field is divided into regions of higher concentration, spatially separated by regions of lower concentration; we call these regions of higher concentration "boluses." When the water column is density stratified, a "peeling-off" effect of the outer portions of the rising wastewater plume is observed. The outer portions "peel-off" into a vertical series of subsurface plumes at different depths within the water column. The rate of dilution with range for a purely surficial plume which existed in January 1988 is compared within the rate of dilution with range of subsurface plume which existed in June of 1988. In the surface plume, a much slower dilution rate is observed for acoustical, dye and fecal streptococcal subfields, while a somewhat slower dilution rate was observed for the fecal coliform. In the subsurface plume, a much slower dilution rate is observed. In addition to dilution with range, mean value, standard deviation and the peak-to-mean values are presented as a function of range for a specific ship transect.

AO-040

RONA, P.A., and D.A. Clague. Geologic controls of hydrothermal discharge on the northern Gorda Ridge. Geology 17:1097-1101 (1989).

An investigation of a 10 x 10 km area near an axial high of the rift valley of the northern Gorda Ridge by using bathymetry, side-scan sonar, and bottom photography where prior water-column surveys indicated ongoing high-temperature hydrothermal discharge reveals that the discharge is localized by specific tectonic and volcanic conditions. The discharge occurs where faults having a predominant ridge parallel and an anomalous subsidiary ridge-oblique tectonic trend intersect at the southern end of a linear ridge on the east wall and at another site at the base of the east wall of the rift valley. Hydrothermal alteration of basalt talus and stratiform hydrothermal precipitates produced by past activity occur where faults and fissures with the same two tectonic trends intersect near a fault having a third ridge-transverse trend at a 1 x 1 km zone of sheet flows on the floor of the rift valley. Present and past hydrothermal discharge in this area is controlled by the intersection of an axis-parallel tectonic trend common to all spreading centers having axis-oblique trends related to the regional stress field near the shallowest and volcanically most productive part of the ridge segment.

AO-041

RONA, P.A., and K.G. Speer. An Atlantic hydrothermal plume: Trans-Atlantic Geotraverse (TAG) area, Mid-Atlantic Ridge crest near 26°N. Journal of Geophysical Research 94(B10):13,879-13,893 (1989).

The physical characteristics of an Atlantic hydrothermal plume and its seafloor sources are described from the first data set of water column properties associated with a high-temperature source area at a slow-spreading oceanic ridge. The observations comprise five near-bottom tows of a camera (color video and still) temperature sensor array through the buoyant portion and 23 conductivity-temperature-depth (CTD) profiles through the neutrally buoyant portion of the plume made at the Trans-Atlantic Geotraverse hydrothermal field in the rift valley of the Mid-Atlantic Ridge at 26°08'N, 44°49'W in July 1985. The source area is a mound up to 250 m wide and 50 m high constructed primarily of massive sulfides between depths of 3,620 and 3,670 m at the base of the east wall. Flow and discharge regimes systematically changed from the center to the edge of the mound. High-temperature black smokers vented at fast rates (> 1 m/s) from discrete sulfide chimneys and at slow rates from fractures, and clear solutions vented at slow rates from diffuse sources in the inner zone of the mound; intermediate-temperature blue-white and white smokers vented at slow rates from discrete sulfide/sulfate chimneys, and clear solutions vented from diffuse sources in the middle zone; patchy, diffuse discharge of clear solutions through sulfide talus occurred in the outer zone. The diffuse discharge of clear solutions and the discrete discharge from the white smokers were observed to turbulently rise up to several meters above the seafloor where the discharge was laterally advected in prevailing laminar flow at several centimeters per second. A convective heat flux of 8.8×10^6W for only the black anomalies was measured with the towed array; this value is intermediate between values estimated for entire vent fields at the fast-spreading East Pacific Rise. Discharge from the black smokers rose to form the neutrally buoyant portion of the plume that was cold and fresh relative to surrounding seawater, where it attained density equilibrium between 190 and 350 m above the mound. In contrast, hydrothermal plumes observed in the Pacific were warm and salty relative to surrounding seawater. The difference is attributed to the effect on plume density of entrainment during rise through opposite salinity profiles that decrease downward in the Atlantic and increase downward in the Pacific, resulting in different temperature-salinity compensations at neutral buoyancy. The temperature difference between the neutrally buoyant portion of the plume and surrounding seawater (negative for the Atlantic; positive for the Pacific) is not a unique function of convective heat flux from a source area, as a consequence of both the effect of the entrainment of salinity on plume density and the separation of diffuse and discrete components of discharge. The hydrothermal plume and the hydrothermal mound are inferred to have grown in size and complexity in response to the development of hydrothermal flow and discharge regimes for at least the past 10^4 years.

AO-042

RONA, P.A., R.P. Denlinger, M.R. Fisk, K.J. Howard, G.L. Taghon, K.D. Klitgord, J.S. McClain, G.R. McMurray, and J.C. Wiltshire (Federal/State Gorda Ridge Technical Task Force Working Group B). Major off-axis hydrothermal activity on the northern Gorda Ridge. Geology 18:493-506 (1990).

The first hydrothermal field on the northern Gorda Ridge, the Sea Cliff hydrothermal field, was discovered and geologic controls of hydrothermal activity in the rift valley were investigated on a dive series using the DSSV Sea Cliff. The Sea Cliff hydrothermal field was discovered where predicted at the intersection of axis-oblique and axis-parallel faults at the south end of a linear ridge at mid-depth (2,700 m) on the east wall. Preliminary mapping and sampling of the field reveal: a setting nested on nearly sediment-free fault blocks 300 m above the rift valley floor 2.6 km from the axis; a spectrum of venting types from seeps to black smokers; high conductive heat flow estimated to be equivalent to the convective flux of multiple black smokers through areas of the seafloor sealed by a caprock of clastic breccia primarily derived from basalt with siliceous cement and barite pore fillings; and a vent biota with Juan de Fuca Ridge affinities. These findings demonstrate the importance of off-axis hydrothermal activity and the role of the intersection of tectonic lineations in controlling hydrothermal sites at seafloor spreading centers.

AO-043

ROSENTHAL, S.L. Summary of the special sessions on Hurricane Hugo. 70th Annual Meeting of the American Meteorological Society, Anaheim, CA, February 4-9, 1990. Bulletin of the American Meteorological Society 71(9):1339-1342 (1990).

No abstract.

AO-044

SHAPIRO, L.J., and K.V. OOYAMA. Barotropic vortex evolution on a beta plane. Journal of the Atmospheric Sciences 47(2):170-187 (1990).

A barotropic, primitive equation (shallow water) model is used on the beta plane to investigate the influence of divergence, total relative angular momentum (RAM) and advective nonlinearities on the evolution of a hurricane-like vortex. The multinested numerical model is based on the spectral application of a finite element representation. The undisturbed fluid depth is taken to be 1 km. Scaling of the vorticity equation, in conjunction with a Bessel function spectral decomposition, indicates that divergence should have a very small effect on the hurricane motion. Simulations with an initially symmetric cyclonic vortex in a resting environment confirm this analysis, and contradict previous published studies on the effect of divergence in a barotropic model. During a 120 h simulation the cyclonic vortex develops asymmetries that have an influence far from the initial circulation. The total RAM within a large circle centered on the vortex decreases with time, and then oscillates about zero. For circles with radii < 1000 km, the total RAM approaches, but does not reach, zero. An angular momentum budget indicates that the horizontal angular momentum flux tends to counteract the net Coriolis torque on the vortex. If the total RAM of the initial symmetric vortex is zero, the weak far-field asymmetries are essentially eliminated. The motion of the vortex is not, however, related to the RAM in any simple way. Within a few days the near-vortex asymmetries reach a near-steady state. The Asymmetric Absolute Vorticity (AAV) is nearly uniform within ~350 km of the vortex center. The homogenization of AAV, which occurs within the closed vortex gyre, is likely due to shearing by the symmetric wind, combined with removal of energy at the smallest scales. The homogenization effectively neutralizes the planetary beta effect, as well as the vorticity associated with an environmental wind.

AO-045

Tziperman, E., and W.C. THACKER. An optimal control/adjoint equations approach to studying the oceanic general circulation. American Meteorological Society 19:1471-1485 (1989).

An efficient procedure is presented for analyzing oceanographic observations with the aid of a general circulation model. Poorly known model parameters, such as eddy mixing coefficients, surface forcing and tracer boundary fluxes, can be calculated by fitting model results to observations. Optimal estimates for all model fields, including the observed ones, can then be computed by running the model with the best-fit values of the calculated parameters. Information about the resolution and the error-covariances of the model parameters can be computed. This information is shown to be very valuable for critically evaluating how well the data determine the parameter's values. An adjoint model, similar in structure to the numerical model, uses information on model-data misfit to improve estimates of the unknown model parameters, and improve the fit to observations. The procedure is illustrated using simulated data and a simple, barotropic, nonlinear, quasi-geostrophic model. Examples are discussed in which friction parameters, wind forcing, and the steady-state circulation are determined from simulated vorticity and streamfunction observations.

AO-046

WILLIS, P.T., and A.J. Heymsfield. Microphysical trajectories in tropical cyclones. Preprints, Conference on Cloud Physics, San Francisco, CA, July 23-27, 1990. American Meteorological Society, Boston, 666-671 (1990).

No abstract.

AO-047

WILLOUGHBY, H.E. Gradient balance in tropical cyclones. Journal of the Atmospheric Sciences 47(2):265-274 (1990).

Analysis of a large inventory of in-situ observations from research aircraft shows that the gradient wind approximates the axisymmetric swirling flow in the free atmosphere within 150 km of the centers of Atlantic hurricanes and tropical storms. In the middle and lower troposphere, the rms difference between azimuthal mean swirling and gradient winds is typically < 1.5 m s^{-1} with zero bias. This balance prevails only for the aziumuthal mean, not locally, nor is balance to be expected in either the surface friction layer or the upper tropospheric outflow layer, where the radial flow is comparable with the swirling flow. It is theoretically possible that axisymmetric supergradient flow may occur in response to rapid radial acceleration where the radial flow slows in the friction layer beneath the eyewall or where it converges into intense diabatically-forced updrafts. Nevertheless, the observations in the free lower and midtroposphere show that systematic departures of the azimuthal mean vortex from balance are too small to measure.

AO-048

WILLOUGHBY, H.E. Linear normal modes of a moving, shallow-water barotropic vortex. Journal of the Atmospheric Sciences 47(17):2141-2148 (1990).

Calculations with a linear semispectral model of a moving tropical-cyclone-like barotropic vortex (Willoughby, 1988) show that a vortex with cyclonic circulation throughout exhibits unphysically fast poleward motion on a beta plane, but a vortex with enough anticyclonic circulation at its periphery to make the total relative angular momentum (L_R) small moves slowly. The high poleward speed arises because the vortex has a linear normal mode at zero frequency, where the beta effect forces asymmetric perturbations. Advection of planetary vorticity by the axisymmetric circulation forces this normal mode at a rate proportional to L_R. Because the governing equations are third-order in time, as many as three linear normal modes are possible. A completely cyclonic vortex has three repeated stable normal modes at zero frequency, whereas one with small L_R has a single stable mode at zero frequency and a conjugate pair of barotropically unstable modes. The frequency of the unstable modes lies at the most anticyclonic rotation frequency of the axisymmetric circulation, and the growth rate is slow; the e-folding time is typically 75 days. If the fluid is made very shallow, the stable normal mode moves away from zero frequency. In this situation, the beta effect fails to force the resonance, and the vortex propagates westward much as a planetary Rossby wave does. In this model, meridional motion of vortices with $L_R = 0$ always acts to adjust L_R toward zero through conservation of absolute angular momentum. Since the asymmetric perturbations are Rossby waves that propagate upon the radial gradient of mean relative vorticity, the mode at zero frequency experiences critical--radius absorption where the mean swirling wind is zero--at the boundary between cyclonic and anticyclonic mean circulation and at the edge of the vortex. Regardless of the sign of L_R, the wave momentum convergence is concentrated at these critical radii and weakens the circulation while expanding it spatially. When $L_R = 0$, waves emanating from the cyclonic and anticyclonic circulations interfere destructively, so that the vortex radiates no angular momentum to its environment.

AO-049

WILLOUGHBY, H.E. Temporal changes of the primary circulation in tropical cyclones. Journal of the Atmospheric Sciences 47(2):242-264 (1990).

More than 900 radial profiles of in-situ aircraft observations collected in 19 Atlantic hurricanes and tropical storms over 13 years confirm that the usual mechanism of tropical cyclone intensification involves contracting maxima of the axisymmetric swirling wind. Radar shows that annuli of convective echoes accompany the wind maxima. These features, called convective rings, exist and move inward because latent heat released in the rings leads to descent, adiabatic warming, and rapid isobaric height falls in the area they enclose. The radial change in rate of isobaric height fall is concentrated at the inner edge of the wind maximum, causing the gradient wind to increase there and the maximum to contract. Vigorous convection organized in rings invariably causes well-defined, inward-moving wind maxima, but when convection is weak, the rings are also weak or even absent. In this case, the swirling wind may be nearly constant with radius and change slowly in time. Hurricanes that have a single, vigorous, axisymmetric ring strengthen rapidly. Although a series of minor convective rings may support steady strengthening, development is more generally episodic. When asymmetric convection erupts near the center of tropical storms or weak hurricanes, it may cause intensification to

falter and the cyclone tracks to become irregular. In intense hurricanes, outer convective rings may form around the pre-existent eyewalls, contract, and strangle the original eyewalls, halting intensification or causing weakening.

AO-050

WILLOUGHBY, H.E., J. Masters, and C. Landsea. A record minimum sea level pressure observed in Hurricane Gilbert. Monthly Weather Review 117(12):2824-2828 (1989).

On 13 September 1988, Hurricane Gilbert attained an extreme minimum sea level pressure, estimated to be 885 hPa from aircraft reconnaissance reports at the time. Postseason analysis indicates that the flight-level pressure, P, upon which this figure is based requires correction upward. In typhoons with sea level pressures < 900 hPa, comparison between sea level pressures measured by dropsonde and those estimated by the same method used in Gilbert indicates that, in addition to the error in P, the estimation has a bias toward low pressure. Although the aircraft did not release a dropsonde in the eye at minimum pressure, it is possible to calculate hydrostatic sea level pressures by assuming a variety of plausible thermal structures below flight level. With corrected P, both the statistical extrapolation with its bias removed and the hydrostatic calculations show that a revised value of 888 $\pm$ 2 hPa is closer to the true minimum sea level pressure. The standard deviation of the various approximations means that the probability is < 3% that the actual minimum failed to reach a value below 892 hPa, the old record for a hurricane in the Atlantic Basin set by the Labor Day Hurricane of 1935.

AO-051

WOOLDRIDGE, A.L., S.E. Haggerty, P.A. RONA, and C.G.A. Harrison. Magnetic properties and opaque mineralogy of rocks from selected seafloor hydrothermal sites at oceanic ridges. Journal of Geophysical Research 95(B8):12,351-12,374 (1990).

Magnetic properties (natural remanent magnetization (NRM), susceptibility (χ), Curie point temperature (T_c), saturation isothermal remanent magnetization (IRM_s), and Koenigsberger ratio (Q)) and opaque mineralogy were determined for basalts, diabases, gabbros, peridotites, and serpentinites collected by dredging and submersible from the rift valley at five hydrothermal sites (15°N, 17°N, 23°N (the Snake Pit hydrothermal field), 26°N (the TAG hydrothermal field) on the Mid-Atlantic Ridge, and 42°N (the Sea Cliff hydrothermal field) on the northern Gorda Ridge). The magnetomineralogy is interpreted in terms of deuteric hydrothermal metasomatic, and ambient seawater alteration. Evidence for unequivocal magnetic mineral modification by hydrothermal action is present only in a small percentage of extrusive basalts but is pervasive in diabases, gabbros, and ultramafic rocks. This lithologic distribution suggests a progressive increase in alteration intensity with depth in the oceanic crust and upper mantle from minor low-temperature alteration in young surface basalts to more pervasive high-temperature alteration in diabases, gabbros, and peridotites. The studies reveal distinct correlations between magnetization intensity, thermomagnetic behavior, and magnetic mineralogy, grain size, style, and intensity of alteration and rock type. Basalts have the highest NRM intensities and the lowest Curie points (105°-294°C); basalts with NRM/IRM_s ratios less than 10^{-2} may have been remagnetized and have NRM intensities and Q values much lower (one-third and one-half, respectively) than basalts with NRM/IRM_s ratios of 10^{-2} or greater. In the oceanic lithospheric suite examined, remanent (Q > 1) magnetization is present in basalts and induced magnetization (Q < 1) occurs in metabasalts and the other rock types. Layer 2A basalts are the source of median valley magnetic anomalies. The magnetic source may shift from the surface to deeper horizons with progressive seafloor aging and enhanced deuteric oxidation in layer 2B dikes and layer 3 gabbros and the formation of magnetite in serpentinized peridotites. This shift is influenced by fluctuations in the Curie isotherm related to the duration of active magma chambers and convective hydrothermal cells. The magnetic and mineralogic properties of oceanic rocks determined show the effects of a wide range of alteration processes that are variously related to depth in oceanic lithosphere, magmatic cooling history, and hydrothermal circulation.

CLIMATE MONITORING AND DIAGNOSTICS LABORATORY

CM-001

Brown, T.J., and J.A. Flueck. Exploratory linear (regression) modeling of El Niño activity. Preprints, 11th Conference on Probability and Statistics in Atmospheric Sciences, Monterey, CA, October 1-5, 1989. American Meteorological Society, Boston, 244-248 (1989).

No abstract.

CM-002

Brown, T.J., J.A. Flueck, J.A. Joselyn, and J.J. Stephenson. Evaluation of the 10.7 cm solar flux using contingency tables and visual displays. Preprints, 11th Conference on Probability and Statistics in Atmospheric Sciences, Monterey, CA, October 1-5, 1989. American Meteorological Society, Boston, 315-317 (1989).

No abstract.

CM-003

BODHAINE, B.A. Barrow surface aerosol. Atmospheric Environment 23(11):2357-2369 (1989).

Measurements at Barrow during the first Arctic Gas an Aerosol Sampling Program (AGASP-I), conducted in March-April 1983, showed a series of aerosol events detected at the ground that coincided with rapid long-range transport paths from Eurasia to the vicinity of Barrow. These events were strongly correlated with aerosol loading in the vertical column (optical depth). Aerosol and meteorological measurements at Barrow during the second AGASP (AGASP-II), conducted in April 1986, indicate no rapid long-range transport from lower-latitude source regions to the vicinity of Barrow, and only limited vertical transport from above the boundary layer to the surface. Aerosol size distribution measurements in the 0.005-0.1 μm diameter size range using a Nuclepore-filter diffusion battery apparatus showed a median diameter of about 0.01 μm during times of high condensation nucleus (CN) concentrations and 0.05 μm during low concentrations. Aerosol black carbon concentrations exceeding 200 ng m^{-3} were detected at the surface and were more strongly correlated with CN concentrations than with aerosol scattering extinction (σ_{sp}), suggesting that aerosol carbon was generally associated with small particles rather than large particles. A continuous record of CN and σ_{sp} measurements is available from 1976 to the present. The σ_{sp} data show a strong annual cycle, having a maximum exceeding 10^{-5} m^{-1} in the winter and spring (the Arctic haze), and a minimum of about 10^{-6} m^{-1} in the summer and fall. The CN data show a semiannual cycle, having a maximum of several hundred per cubic centimeter coinciding with the maximum in σ_{sp} in early spring, and a secondary maximum in August. Minima in CN concentration of about 100 cm^{-3} occur in summer and late fall. No significant diurnal cycle appears in either the CN or σ_{sp} long-term records.

CM-004

BODHAINE, B.A., and M.K. SHANAHAN. Condensation nucleus and aerosol scattering extinction measurements at the South Pole Observatory: 1979-1988. NOAA DR ERL CMDL-1, 148 pp. (1990).

The Geophysical Monitoring for Climatic Change (GMCC) program under the National Oceanic and Atmospheric Administration (NOAA) operates an atmospheric-monitoring observatory at the Amundsen-Scott Station, South Pole, Antarctica. Continuous measurements of aerosol scattering extinction coefficient (σ_{sp}) and condensation nucleus (CN) concentration are obtained at the observatory. A General Electric automatic, continuous CN counter has been operated since 1974 to measure the CN concentration. The aerosol scattering extinction coefficient has been measured by a four-wavelength nephelometer since 1979. The aerosol scattering extinction coefficient is used to calculate the Angstrom exponent, which is related to the aerosol size distribution. A Pollak CN counter provides discrete measurements that are used for calibration of the continuous CN counter. All three instruments provide data that are representative of the background aerosol climatology at the South Pole. The CN data show a repeatable annual cycle, having a maximum exceeding 100 cm^{-3} in the austral summer and a minimum of about 10 cm^{-3} in the winter. The aerosol scattering extinction coefficient data show a complicated annual cycle, having a maximum in the austral winter, a secondary maximum in summer, and a minimum in May. Calculations of the Ar gstrom exponent suggest that larger particles are found in the winter than in the summer.

CM-005

BODHAINE, B.A., J.J. DE LUISI, J.F. BOATMAN, M.J. Post, and J. Rosen. The front range lidar, aircarft, and balloon experiment. NOAA DR ERL CMDL-2, 27 pp. (1990).

Data are presented from the Front Range Lidar, Aircraft, and Balloon (FRLAB) experiment, which was performed near Boulder, Coloraado, on July 26, 1989. The purpose of this experiment was to make simultaneous measurements of aerosol profiles in the atmosphere using ground-based CO_2 and ruby lidar; airborne nephelometer, condensation nucleus (CN) counter, and aethalometer; and balloonborne backscattersonde. The data provide a unique inter-comparison between several diverse types of instruments as well as a quantitatively consistent evaluation of the amount of non-Rayleigh scattering occurring in the tropospheric clean region where lidar profiles are often normalized.

CM-006

BODHAINE, B.A., E.G. DUTTON, J.J. DELUISI, G.A. HERBERT, G.E. Shaw, and A.D.A. Hansen. Surface aerosol measurements at Barrow during AGASP-II. Journal of Atmospheric Chemistry 9:213-224 (1989).

Measurements at Barrow during the second Arctic Gas and Aerosol Sampling Program (AGASP-II), conducted in April 1986, showed more rapid long-range transport from lower-latitude source regions to Barrow, and only limited vertical transport from above the boundary layer to the surface. New aerosol size distribution measurements in the 0.005-0.1 μm diameter size range using a Nuclepore-filter diffusion battery apparatus showed a median diameter of about 0.01 μm during times of high condensation nucleus (CN) concentrations. Aerosol black carbon concentrations exceeding 400 ng m^{-3} were detected at the surface and were more strongly correlated with CN concentrations than with aerosol scattering extinction (σ_{sp}), suggesting that aerosol carbon was generally associated with small particles rather than large particles. Measurements at Barrow during AGASP-I, conducted in March-April 1983, showed a series of aerosol events detected at the ground that were caused by rapid long-range transport paths to the vicinity of Barrow from Eurasia. These events were strongly correlated with aerosol loading in the vertical column (optical depth).

CM-007

Bridgman, H.A., R.C. Schnell, G.A. HERBERT, B.A. BODHAINE, and S.J. OLTMANS. Meteorology and haze structure during AGASP-II, Part 2: Canadian arctic flights, 13-16 April 1986. Journal of Atmospheric Chemistry 9:49-70 (1989).

In April 1986, a well-instrumented NOAA WP-3D research aircraft conducted three flights in the Canadian Arctic tied to the Canadian Atmospheric Environment Service baseline station in Alert, Northwest Territories. Two of the flights were coordinated with the National Aeronautical Establishment of Canada Twin Otter and the University of Washington C-131 research aircraft. The haze observed in the Canadian Arctic was well-aged and mixed throughout the troposphere in concentrations well below those observed during the previous weeks in the Alaskan Arctic. Over the ice, beneath the surface temperature inversion, ozone was generally depleted to near zero. Over the coast at Alert, there is evidence that topography and downslope winds reduce the strength of the inversion, thus allowing lower tropospheric gases and aerosols to mix down to the surface. At the top of the troposphere, an aerosol-depleted region was observed. In lower stratosphere, aerosol concentrations were elevated above those observed in the troposphere.

CM-008

Bridgman, H.A., R.C. Schnell, J.D. Kahl, G.A. HERBERT, and E. Joranger. A major haze event near Point Barow, Alaska: Analysis of probable source regions and transport pathways. Atmospheric Environment 23(11):2537-2549 (1989).

On 2-3 April 1986, an unusually dense Arctic haze band with distinct horizontal and vertical boundaries was intercepted by a NOAA WP-3D aircraft north of Barrow, Alaska during the second Arctic Gas and Aerosol Sampling Program (AGASP-II). Within this haze event, condensation nuclei (CN) counts exceeded 70,000 cm^{-3}, and aerosol scattering extinction coefficients (b_{sp} were >70 x 10^{-6} m^{-1}. SO_2 concentrations in the haze were 1[illegible] ppbv. Synoptic meteorological data collected in Arctic and subArctic regions were supplemented with trajectory analyses to determine the probable source regions and transport pathways of the haze. Analyses of these data, along with surface air quality measurements in Norway, suggest that the haze originated in central Europe 10 days earlier. The transport pathway followed a typical pattern characteristic of spring haze transport in the Arctic.

CM-009

BUTLER, J.H., J.W. ELKINS, T.M. THOMPSON, and K.B. Egan. Tropospheric and dissolved N_2O of the West Pacific and East Indian Oceans during the El Niño southern oscillation event of 1987. Journal of Geophysical Research 94(D12):14,865-14,877 (1989).

Over 2000 measurements of N_2O in the surface water and marine troposphere along with 650 measurements of N_2O from depths of up to 6000 m were obtained from the W. Pacific and E. Indian oceans during the late spring and early summer of 1987. The precision (1 standard deviation) for tropospheric, surface water, and deep-water measurements was 0.2%, 1%, and 2%. The results show a latitudinally weighted, mean interhemispheric difference of 0.97 ppb, which suggests that 2/3 of the global flux of N_2O into the atmosphere derives from sources in the northern hemisphere. The mean surface water saturation anomaly was only 2.5% during this study, which included subtropical gyres, current confluences and divergences, and some shelf waters. Supersaturations of dissolved N_2O that might normally be associated with equatorial upwelling in the W. Pacific were depressed along with other upwelling indicators. Our surface water flux estimates suggest that the oceanic flux of N_2O during an El Niño year may be less than 50 Gmol yr^{-1} (about 10% of the mean annual flux of N_2O into the troposphere). Deep-water N_2O concentrations, which could be predicted with reasonable certainty from salinity, temperature, dissolved O_2, and pressure, were highest in N. Pacific waters and lowest in the higher latitudes of S. Pacific and E. Indian oceans.

CM-010

CONWAY, T.J., and L.P. Steele. Carbon dioxide and methane in the Arctic atmosphere. Journal of Atmospheric Chemistry 9:81-99 (1989).

Fifty flask air samples were taken during April 1986 from a NOAA WP-3D Orion aircraft which flew missions across a broad region of the Arctic as part of the second Arctic Gas and Aerosol Sampling Program (AGASP II). The samples were subsequently analyzed for both carbon dioxide (CO_2) and methane (CH_4). The samples were taken in well-defined layers of Arctic haze, in the background troposphere where no haze was detected, and from near the surface to the lower stratosphere. Vertical profiles were

specifically measured in the vicinity of Barrow, Alaska to enable comparisons with routine surface measurements made at the NOAA/GMCC observatory. Elevated levels of both methane and carbon dioxide were found in haze layers. For samples taken in the background troposphere we found negative vertical gradients (lower concentrations aloft) for both gases. For the entire data set (including samples collected in the haze layers) we found a strong positive correlation between the methane and carbon dioxide concentrations, with a linear regression slope of 17.5 ppb CH_4/ppm CO_2, a standard error of 0.6, and a correlation coefficient (r^2) of 0.95. This correlation between the two gases seen in the aircraft samples was corroborated by in-situ surface measurements of these gases made at the Barrow observatory during March and April 1986. We also find a similar relationship between methane and carbon dioxide measured concurrently for a short period in the moderately polluted urban atmosphere of Boulder, Colorado. We suggest that the strong correlation between methane and carbon dioxide concentrations reflects a common source region for both, with subsequent long-range transport of the polluted air to the Arctic.

CM-011

DELUISI, J.J. Stratospheric Aerosols: Errors to the Umkehr measurements. Atmospheric Ozone, Proceedings of the 1st American-Soviet Meeting on Atmospheric Ozone, Moscow, U.S.S.R., February 1987, V.U. Khattatov (editor) 24-35 (1989).

Atmospheric aerosols are known to affect the Umkehr observation of vertical ozone profiles because they produce additional optical extinction and scattering that are not accounted for in the Umkehr measurement inversion algorithm. Stratospheric aerosols may also affect other types of measurements such as the Solar Backscatter Ultra Violet (SBUV) satellite and Solar Mesospheric Explorer (SME) as demonstrated by the recent injection of immense amounts of dust from the eruption of El Chichon volcano in the spring of 1982. This presentation will discuss the nature of the stratospheric aerosol error to Umkehr observations and the types and sources of stratospheric aerosol information available to correct Umkehr measurements, including some interesting phenomena associated with stratospheric aerosol properties and transport.

CM-012

DELUISI, J.J. Trends in atmospheric ozone. Atmospheric Ozone, Proceedings of the 1st American-Soviet Meeting on Atmospheric Ozone, Moscow, U.S.S.R., February 1987, V.U. Khattatov (editor) 7-17 (1989).

The largest temporal record of atmospheric total ozone and vertical profile is that produced from the Dobson network. The record begins near the end of the 1950's and extends to the present. There are approximately 35 stations that have produced a sufficiently long record of total ozone data suitable for trend analysis, and 13 of these stations have produced Umkehr vertical ozone profile data suitable for trend analysis. The Solar Backscatter Ultra Violet (SBUV) satellite experiment has produced a data set beginning in November of 1979 and extending to the present. Some baseline long-term measurements of surface ozone have been made by the Geophysical Monitoring for Climatic Change (GMCC) of NOAA's Air Resources Laboratory. The U.S. Environment Protection Agency and certain European research centers have been involved with surface ozone measurements; however, these measurements are not likely to be classified as baseline suitable for trend analysis because of their proximity to local sources. This presentation centers mainly on stratospheric ozone which may have been altered because of photochemical destruction by long-lived anthropogenic gases such as fluorocarbons.

CM-013

DELUISI, J.J., D.U. Longenecker, and C.L. Mateer. An objective method of correcting Umkehr measurements for volcanic aerosol error. Ozone in the Atmosphere. Proceedings, Quadrennial Ozone Symposium 1988 and Tropospheric Ozone Workshop, Göttingen, FRG, August 8-13, 1988, R.D. Bojkov and P. Fabian, (eds.), A. Deepak, Hampton, Virginia, 100-104 (1989).

An objective method of calculating errors to Umkehr measurements for stratospheric aerosol interference was developed and used on a selected set of Umkehr data. The method involves theoretical calculations that include observations of stratospheric ozone and aerosols. Stratospheric ozone and aerosol profile data used to calculated the errors to the Umkehr measurements are derived from ozonesonde observations and observations provided by five lidar stations in the northern hemisphere middle latitudes. Optical properties of the stratopsheric aerosol are deduced from photometric observations and in situ observations of aerosol size distribution. The calculated errors are used to correct Umkehr data for several stations in the Northern middle latitude region. The corrected data display noteworthy variations, one of which is an obvious decrease in ozone concentration in the upper stratosphere during the first half of the 1980 decade. However, the decrease does not appear to be out of the range of variations seen in the long-term data set.

CM-014

DELUISI, J.J., E.G. DUTTON, G.L. KOENIG, D.U. Longenecker, and P.J. Reddy. Zenith-sky cloud detection for automated Dobson Umkehr measurements. Ozone in the Atmosphere. Proceedings, Quadrennial Ozone Symposium 1988 and Tropospheric Ozone Workshop, Göttingen, FRG, August 8-13, 1988, R.D. Bojkov and P. Fabian, (eds.), A. Deepak, Hampton, Virginia, 736-738 (1989).

Seven Dobson instruments have been automated by the Geophysical Monitoring for Climatic Change program (GMCC) for unattended operation to obtain short and conventional Umkehr measurements. The large-particle scattering condition of the zenith sky, primarily clouds, is manifested in the Umkehr measurement, which is accepted or rejected on the basis of the smoothness of the Umkehr curve. A sensitive photometer (zenith sky cloud detector, ZSCD) was designed and developed by GMCC to observe approximately the same portion of the zenith sky as the Dobson instrument does during operation, but at a different wavelength (862 nm). The ZSCD information is used as a means to assess the quality of each Umkehr observation in addition to aiding the diagnosis of a malfunctioning instrument.

CM-015

DELUISI, J.J., D.U. Longenecker, P.K. Bhartia, S. Taylor, and C.L. Mateer. Ozone profiles by Umkehr, SBUV, and ozonesonde: A comparison including the inversion algorithms for Umkehr and SBUV. Ozone in the Atmosphere. Proceedings, Quadrennial Ozone Symposium 1988 and Tropospheric Ozone Workshop, Göttingen, FRG, August 8-13, 1988, R.D. Bojkov and P. Fabian, (eds.), A. Deepak, Hampton, Virginia, 206-210 (1989).

The ultraviolet techniques used by the Umkehr and solar backscattered ultraviolet (SBUV) satellite are similar in principle; however, their mathematical constructions differ somewhat. Because of this and because the mathematical radiative transfer calculations in the inversion algorithms for the two techniques may not perfectly simulate true atmospheric conditions, they may not produce identical ozone profiles when simultaneously viewing the same portion of the atmosphere. To determine the Umkehr-SBUV-comparison result that could be "best expected" from an idealized situation, each type of observation was simulated using radiation transfer theory, ozone absorption and Rayleigh scattering coefficients for the Umkehr and SBUV algorithms, and 11 profiles from monthly averaged Stratospheric Aerosol and Gas Experiment (SAGE II) data supplemented by ozonesonde data. Then error noise was added to these simulated measurements and deduced ozone profiles by each technique. The resulting profiles are compared here for bias, mean square deviation (without bias), and correlation. The SAGE II data are included in the comparison. For the real case, observed Umkehr and SBUV profiles, and observed Umkehr and ozonesonde profiles are compared. The final results are interpreted in the context of the "best expected" results, and the combined "effective" atmospheric instrumental, and algorithm error.

CM-016

DIAZ, H.F. Analysis of regional scale precipitation fluctuations on decadal time scales. Proceedings, WMO International Workshop on Precipitation Measurement, St. Moritz, Switzerland, December 1989. Swiss Federal Institute of Technology, Zurich, 505-511 (1990).

No abstract.

CM-017

DIAZ, H.F. Large-scale differences in atmospheric circulation patterns associated with wet and dry regimes in the United States. Proceedings, Symposium on Global Change Systems--Special Sessions on Climate Variations and Hydrology, Anaheim, CA, February 5-9, 1990. American Meteorological Society, Boston, 184-188 (1990).

No abstract.

CM-018

DUTTON, E.G. Comments on "Major volcanic eruptins and climate: A critical evaluation." Journal of Climate 3(5):587-588 (1990).

No abstract.

CM-019

DUTTON, E.G., J.J. DELUISI, and G. HERBERT. Shortwave aerosol optical depth of Arctic haze measured on board the NOAA WP-3D during AGASP-II, April 1986. Journal of Atmospheric Chemistry 9:71-79 (1989).

Measurements of spectral aerosol optical depth in the Alaskan and Canadian Arctic were made from the NOAA Lockheed WP-3D aircraft as part of the second Arctic Gas and Aerosol Sampling Program (AGASP-II) during April 1986. The flight tracks and altitudes flown enabled measurements of the vertical and horizontal distribution of aerosol optical depth in the troposphere as well as direct determination of the stratospheric component. Tropospheric aerosol optical depth ranged from about 0.1 to 0.7. The factor of 7 variability sometimes occurred within 50 km horizontally; comparable variability occurred within less than 1 to 2 km vertically. The Angstrom exponents of the spectral optical depths ranged from 0.5 to 2.0, and some of the variability was apparently related to distinct aerosol regimes.

CM-020

ELKINS, J.W., and R.M. ROSSON (eds.). Geophysical Monitoring for Climatic Change No. 17 Summary Report 1988. Environmental Research Laboratories, Boulder, CO, 142 pp (1989).

No abstract.

CM-021

Erickson, D.J., III, and J.A. Taylor. Non-Weibull behavior observed in a model-generated global surface wind field frequency distribution. Journal of Geophysical Research 94(C9):12,693-13,698 (1989).

The frequency distribution of the surface wind speeds at each 4.5° x 7.5° latitude-longitude grid point produced by the National Center for Atmospheric Research community climate model is examined. A modified Kologorov-Smirnov (KS) test was used to

ascertain the extent of Weibull behavior for perpetual January and July model runs. The modified KS test has been applied to 400 days of both perpetual January and July model runs using a 0.5-day time sample. A global map of the KS statistic for each of the January and July control runs has been generated. These maps are presented for both the ocean and land wind fields. For the January oceanic winds, 29.2% of the frequency distributions were non-Weibull at the 95% confidence level. Over land, 35.4% of the wind speed frequency distributions were judged to be non-Weibull. For the July wind speed data, 32,7% of the ocean data sets were judged to be non-Weibull, while for winds over land, 30.2% were found to be non-Weibull. Large areas of Eurasia experience non-Weibull behavior during the January run. The main oceanic latitudinal zones associated with a non-Weibull character are from 5° to 30° in each hemisphere, a feature that is most evident in the July run. The monsoonal winds over the Indian Ocean area almost entirely Weibull. The non-Weibull character of surface wind field frequency distributions may explain, in part, the apparent inability of some surface wind data sets to drive an ocean circulation model through inexact wind forcing.

CM-022

Evans, R.D., G.L. KOENIG, W.D. KOMHYR, J. Easson, and P. Marche. Umkehr observations at five automated Dobson spectrophotometer stations in 1986 and 1987. Ozone in the Atmosphere. Proceedings, Quadrennial Ozone Symposium 1988 and Tropospheric Ozone Workshop, Göttingen, FRG, August 8-13, 1988, R.D. Bojkov and P. Fabian, (eds.), A. Deepak, Hampton, Virginia, 151-154 (1989).

Umkehr observations have been made with automated Dobson spectrophotometers at Poker Flat, Alaska; l'Observatoire de Haute Provence, France; Boulder, Colorado; Mauna Loa Obseratory, Hawaii; and Perth, Australia. The five stations range in latitude from 6°N to 32°. We report on the data obtained only during 1986 and 1987 when adverse effects of El Chichon aerosols on the Umkehr observations were no longer significant. The data set consists of 2199 selected profiles. Averaged seasonal and annual profiles are presented, exhibiting characteristic features related to total ozone amount and station latitude. A brief description of the measurement program, related to data quality is included.

CM-023

Fiocco, G., W.D. KOMHYR, and D. Fuà. Is ozone destroyed during the Antarctic winter in the presence of polar stratospheric clouds? Nature 341:426-427 (1989).

Since the discovery of the springtime Antarctic ozone depletion, a great deal of attention has been given to processes related to aerosol formation and heterogeneous chemistry at low temperatures. Polar stratospheric cloud (PSCs) are frequent features of the southern winter atmosphere, and may provide a site for heterogeneous reactions that lead to ozone destruction. Models have been proposed for the formation of PSCs based on the condensation of HNO_3. An optical radar (lidar) has been operated at Amundsen Scott (South Pole), Antarctica, since the austral summer 1987-88. Observations made during the 1988 polar night show the presence of PSCs. Here we report ozonesonde measurements made quasi-simutaneously at the South Pole which indicate sharp minima of the ozone concentration in the vicinity of the PSCs. Although definitive information is unavailable for unambiguous interpretation of the results, the data may be viewed as evidence either for the role of dynamics in transporting air of different composition in conditions of substantial stability or for processes leading to ozone destruction during the polar winter; the latter may include heterogeneous chemical reactions taking place in the absence of photolysis.

CM-024

Fleig, A.J., D.S. Silberstein, C.G. Wellemeyer, R.P. Cebula, P.K. Bhartia, and J.J. DELUISI. An assessment of the SBUV/TOMS ozone data quality, based on comparison with external data. Ozone in the Atmosphere. Proceedings, Quadrennial Ozone Symposium 1988 and Tropospheric Ozone Workshop, Göttingen, FRG, August 8-13, 1988, R.D. Bojkov and P. Fabian, (eds.), A. Deepak, Hampton, Virginia, 232-237 (1989).

The validation effort of the SBUV/TOMS ozone system is summarized. The long term drift of SBUV/TOMS total ozone relative to the Dobson Network over the eight years from launch through October 1986 is presented and discussed. On February 13, 1987 (early in the ninth year of operation), the optical chopper on the SBUV instrument began to fall out of synchronization. As a result, these comparisons comprise the final validation of the in-sync SBUV data set as a whole. The SBUV drift relative to a 41 station Dobson Network is roughly linear with a slope of approximately -0.42 ± 0.09%/yr, but the TOMS drift is better fit by a two-piece linear model with a common intercept around the middle of 1982. The slopes are -0.25 ± 0.17%/yr during the first period and -0.53 ± 0.15%/yr for the second period. Support for the presence of a downward change in the upper level ozone is provided through comparisons of the SBUV profile ozone with data from the Umkehr Network and SAGE II. Correlation analysis of the seasonal behavior of the total ozone with Dobson measurements and profile ozone with Umkehr and balloons is also presented.

CM-025

Flueck, J.A., and T.J. Brown. An exploratory study of some possible solar and weather relationships. Preprints, 11th Conference on Probability and Statistics in Atmospheric Sciences, Monterey, CA, October 1-5, 1989 325-322 (1989).

No abstract.

CM-026

Franchois, P., G. KOENIG, R.D. Evans, and W.D. KOMHYR. Comparison of ECC ozonesonde and Umkehr profiles at Boulder and Manua Loa, 1985-1987. Ozone in the Atmosphere. Proceedings, Quadrennial Ozone Symposium 1988 and Tropospheric Ozone Workshop, Göttingen, FRG, August 8-13, 1988, R.D. Bojkov and P. Fabian, (eds.), A. Deepak, Hampton, Virginia, 155-159 (1989).

Umkehr observations have been made with an automated Dobson spectrophotomter at Boulder, Colorado, since early 1983, and at Mauna Loa, Hawaii, since early 1984. Numerous balloonborne electrochemical concentration cell (ECC-Komhyr) ozonesonde soundings have also been made at Boulder and at Hilo, Hawaii, located near sea level about 60 km from Mauna Loa Observatory. The Umkehr data are compared with quasi-simultaneously obtained ozonesonde data converted to the layer averaged format of the Umkehr profiles. Comparisons are made for seasonally, annually, and long-term averaged data. Results of the comparison are shown to differ according to season and station location but in general indicate agreement to within ±10% between the measurement methods in Umkehr layers 4 to 6.

CM-027

GRASS, R.D., and W.D. KOMHYR. Ozone in the atmosphere. Traveling standard lamp calibration checks of Dobson ozone spectrophotometers during 1985-1987. Ozone in the Atmosphere. Proceedings, Quadrennial Ozone Symposium 1988 and Tropospheric Ozone Workshop, Göttingen, FRG, August 8-13, 1988, R.D. Bojkov and P. Fabian, (eds.), A. Deepak, Hampton, Virginia, 144-146 (1989).

During 1985-1987, calibrated standard lamps were sent from Boulder to check on the calibration level of 95 Dobson instruments in the global total zone station network. Data received from 81 instruments indicated that 13 were in need of recalibration. Six of the 13 have since been recalibrated by means of direct intercomparison with World Standard Dobson Instrument No. 83.

CM-028

Hansen, A.D.A., T.J. CONWAY, L.P. Steele, B.A. BODHAINE, K.W. Thoning, P. TANS, and T. Novakov. Correlations among combustion effluent species at Barrow, Alaska: Aerosol black carbon, carbon dioxide, and methane. Journal of Atmospheric Chemistry, 9:283-299 (1989).

As part of the second Arctic Gas and Aerosol Sampling Program (AGASP II) continuous measurements of atmospheric aerosol black carbon (BC) were made at the NOAA/GMCC observatory at Barrow, Alaska (71°19'N, 156°36'W) during the period March 21-April 22, 1986. Black carbon is produced only by incomplete combustion of carbonaceous materials and so is a particularly useful atmospheric indicator of anthropogenic activities. The BC data have been analyzed together with the concurrent measurements of carbon dioxide (CO_2), methane (CH_4), and condensation nuclei (CN) that are routinely made at the observatory. All four species showed elevated and highly variable concentrations due to local human activities, principally in the township of Barrow, 7 km to the southwest, and the DEW Line radar installation 1 km to the northwest. We distinguish between those periods of the record that are affected by local activities and those that are not, on the basis of the short-term (periods of up to 1 hour) variability of the continuous CO_2 and CN records, with large short-term variabilities indicating local sources. We identified seven periods of time (events) with durations ranging from 13 to 37 hours when the BC, CO_2, and CH_4 concentrations change smoothly over time, were highly correlated with each other, and were not influenced by local activities. These events had BC/CO_2 ratios in the range (50-103) x 10^{-6}. These ratios are dimensionless since we convert the CO_2 concentrations to units of ng m^{-3} of carbon. Such values of BC/CO_2 are characteristic of the combustion effluent from large installations burning heavy fuel oil or coal, automobiles, and domestic-scale natural gas usage. We conclude that these events are indicative of air masses that have been polluted with combustion emissions in a distant location and then transported to the Arctic. In the absence of species-selective loss mechanisms, these air masses will maintain their combustion effluent signatures during the transport. The BC/CO_2 ratios found for the local combustion activities are consistent with those expected from known combustion processes.

CM-029

HARRIS, J.M., and J.D. KAHL. A descriptive atmospheric transport climatology for the Mauna Loa Observatory, using clustered trajectories. Journal of Geophysical Research 95(D9):13,651-13,667 (1990).

The climatology of long-range atmospheric transport to the Mauna Loa Observatory (MLO) is examined through an analysis of 10-day isobaric back trajectories for the period 1981-1988, computed using the National Meteorological Center's analyzed gridded winds. The trajectories are classified into distinct transport patterns through the use of cluster analysis, a procedure that avoids the somewhat arbitrary classification by compass sector and instead searches for meaningful groupings within the data themselves. The clustering procedure is performed separately for yearly and monthly sets of 500- and 700-hPa trajectories to examine both year-to-year and month-to-month variability in flow characteristics. The dominant transport features are quite similar from year to year, and include frequent summertime easterly flow associated with the trade winds and strong, wintertime westerly flow close to the mean axis of the subtropical jet stream. Veering westerly patterns that approach MLO from the north and northeast dominate during winter/summer transition periods. Other noteworthy features include recurring air mass transport from Saharan and Asian desert regions, infrequent interhemispheric flow from as far as 10°S, and occasional flow from high northern latitudes. Ten-day back trajectories that pass over anthropogenic pollution source regions in western North America are rare.

CM-030

HERBERT, G.A., J.M. HARRIS, and B.A. BODHAINE. Atmospheric transport during AGASP-II: The Alaskan flights (2-10 April 1986). Atmospheric Environment 23(11):2521-2535 (1989).

Kinematic trajectories were computed on isentropic surfaces, in the upwind direction, to determine the origin of the air masses sampled during the Alaskan phase of AGASP-II (Arctic Gas and Aerosol Samping Program) flights. Gridded wind data from the National Meteorological Center were used to compute the trajectories. Trajectories were computed from the centers of the haze layers and regions of high CN concentration whenever possible. Below 1.5 km, in the presence of large-scale ascending motion, the isentropic surfaces descended to below the lowest level for which temperatures were available. In these situations it was not possible to compute trajectories for more than 2-4 days (1000-2000 km). Otherwise, trajectries were computed for 10 days, at 10-K intervals to the lower stratosphere. The Alaskan AGASP-II flights consisted of research flights to Barrow on 2-3 and 9-10 April, and to over the Beaufort Sea, north of Barter Island, on 8 April 1986. During the 2-3 April flight a major haze event was encountered 900 km northwest of Barrow. In this air mass the measured values of aerosol scatteing extinction, and the concentrations of condensation nuclei, aerosol black carbon and SO_2 were significantly higher than background in layers from 1 to 5 km. Trajectroies arriving at 1.8 and 5 km show the haze to have originated as a polluted air mass over Europe 8 days earlier. On 8 April, while the aircraft sampled over the ice-covered Beaufort Sea, the concentration of haze constituents was found to be significanty less than on the first flight. The trajectories to this region indicate that the air had been over the Arctic Basin and northern Canada for the previous week. On the second flight to Barrow, 9-10 April, concentrations of the pollution constituents had decreased further, and only a shallow layer of elevated aerosol scattering extinction values were observed at 1 km. Trajectory analysis indicates that this haze originted over Europe 2 weeks earlier and found its way to Alaska by way of Svalbard and the Greenland Sea. During the 2-3 April flight trajectries at 290 and 300 K passed over south-central Alaska at about the time of the eruption of the Augustine volcano. An increase in aerosol concentrations and a high value of SO_2 immediately below the tropopause over Barrow suggest the presence of volcanic debris. The 290 K trajetory on 8 April also passed downwind of the Augustine volcano while it was erupting, but there was no evidence of debris in that case. Source regions are considered to be at least 1000 km square to be consistent with known uncertainties in trajectory analysis.

CM-031

HERBERT, G.A., R.C. Schnell, H.A. Bridgman, B.A. BODHAINE, S.J. OLTMANS, and G.E. Shaw. Meteorology and haze structure during AGASP-II, Part 1: Alaskan arctic flights Journal of Atmospheric Chemistry 9:17-48 (1989).

The second Arctic Gas and Aerosol Sampling Program (AGASP-II) was conducted across the Alaskan and Canadian Arctic in April 1986, to study the in situ aerosol, and the chemical and optical properties of Arctic haze. The NOAA WP-3D aircraft, with special instrumentation added, made six flights during AGASP-II. Measurements of wind, pressure, temperature, ozone, water vapor, condensation nuclei (CN) concentration, and aerosol scattering extinction (b_{sp}) were used to determine the location of significant haze layers. The measurements made on the first three flights, over the Arctic Ocean north of Barrow and over the Beaufort Sea north of Barter Island, Alaska are discussed in detail in this report of the first phase of AGASP II. In the Alaskan Arctic the WP-3D detected a large and persistent region of haze between 960 and 750 mb, in a thermally stable layer, on 2, 8, and 9 April 1986. At its most dense, the haze contained concentrations >10,000 cm^{-3} and b_{sp} of 80 x 10^{-6} m^{-1} suggesting active SO_2 to H_2SO_4 gas-to-particle conversion. Calculations based upon observed SO_2 concentrations and ambient relative humidities suggest that 10^4-10^5 small H_2SO_4 droplets could have been produced in the haze layers. High concentrations of sub-micron H_2SO_4 droplets were collected in haze. Ozone concentrations were 5-10 ppb higher in the haze layers than in the surrounding troposphere. Outside the regions of haze, CN concentrations ranged from 100 to 400 cm^{-3} and b_{sp} values were about (20-40) $\times 10^{-6}$ m^{-1}. Air mass trajectories were computed to depict the air flow upwind of regions in which haze was observed. In two cases the back trajectories and ground measurements suggested the source to be in central Europe.

CM-032

Johnson, J.E., R.H. GAMMON, J. LARSEN, T.S. BATES, S.J. OLTMANS, and J.C. FARMER. Ozone in the marine boundary layer over the Pacific and Indian Oceans: Latitudinal gradients and diurnal cycles. Journal of Geophysical Research 95(8):11,847-11,856 (1990).

Ozone concentrations in the atmospheric boundary layer of the Pacific and Indian Oceans were measured on four separate oceanographic research cruises (July 1986 May to August 1987, April to May 1988). These measurements show a distinct zone of near zero (≤3 ppb) ozone concentration in the central equatorial Pacific in April-May with ozone increasing in this region over the next four months. The seasonal observed change in the latitudinal gradient of ozone is consistent with previous ozone measurements at Hilo and Samoa by Oltmans and Komhyr (1986) and predictions from an atmospheric general circulation model study (Levy et al., 1985). A significant diurnal cycle of ozone was found in almost all locations with a maximum near sunrise, a minimum in the late afternoon, and a peak-to-peak amplitude of 1 to 2 ppb (10-20%), similar to that predicted by a photochemical model in the low NO_x limit (Thompson and Lenshchow, 1984).

CM-033

Joseph, P.V. Warm pool over the Indian Ocean and monsoon onset. Tropical Ocean-Atmosphere Newsletter, 53, 1-5, (1990).

No abstract.

CM-034

Kahl, J.D., J.M. HARRIS, G.A. HERBERT, and M.P. Olson. Intercomparison of three long-range trajectory models applied to Arctic haze. Tellus 41B:524-536 (1989).

Three long-range trajectory models which have been applied to Arctic haze problems were compared. These models employ diferent parameterizations of vertical motions, and are based on different meteorological analyses. Median horizontal displacements between 5-day trajectory endpoints were mostly in the 800-1000 km range. Model sensitivity to the meteorological data was shown to contribute a substantial component to the overall uncertainty. Based on these comparisons, we estimate that the usefulness of trajectory models after 5 days is limited to the identification of distant source regions with horizontal dimensions on the order of 1000 km.

CM-035

Khalsa, S.J.S. Remote sensing of atmospheric thermodynamics in the tropics. Proceedings, Western Pacific International Meeting and Workshop on TOGA-COARE, Noumea, New Caledonia, May 24-26, 1989, 665-676 (1989).

Extended abstract.

CM-036

Kiladis, G.N., and H.F. DIAZ. Global climatic anomalies associated with extremes in the southern oscillation. Journal of Climate 2(9):1069-1090 (1989).

Composite temperature and precipitation anomalies during various stages of an event in the Southern Oscillation (SO) have been computed for several hundred stations across the globe. Large regions of coherent, significant signals are shown to exist for both extremes of the SO, with warm event signals generally opposite to those during cold events. In addition, during the year preceding the development of an event in the SO (year -1), climatic anomalies tend to be opposite to those during the following year (year 0). This confirms that the biennial tendency of the SO over the Pacific/Indian ocean sectors is also present in more remote regions with climatic signals related to the SO. Many of the signals are consistent enough from event to event to be useful for extended range forecasting purposes.

CM-037

Kiladis, G.N., H. Von Storch, and H. Van Loon. Origin of the South Pacific convergence zone. Journal of Climate 2:1185-1195 (1989).

The importance of the presence of South America and Australia to the existence and orientation of the South Pacific Convergence Zone (SPCZ) during January is explored using the ECMWF T21 model. Each of the continents is removed from the model and replaced with an ocean surface, and the resulting precipitation and circulation associated with the SPCZ are then compared to a perpetual January control run. Results show that the presence of South America and the equatorial Pacific upwelling zone does not appear to be crucial to the SPCZ, but that the removal of Australia destroys the southern monsoon an substantially weakens the western part of the SPCZ. This suggests that the northwest-southeast orientation of the SPCZ during southern summer is more dependent on interactions with the midlatitude westerlies over the South Pacific than on the distribution of sea surface temperature and land over the Southern Hemisphere.

M-038

KOMHYR, W.D., and R.D. McPeters. Dobson spectrophotometer 83: A standard for ground-based and satellite total ozone measurements. Digest of topical meeting on optical remote sensing of the atmosphere, 1990. Optical Society of America, Washington, D.C. 4:398-401, (1990).

Operation of Dobson spectrophotometer 83 since 1962 as a standard for total ozone observations is described, and data obtained with a long-term ozone measurement precision of ±0.5% since 1979 are compared with TOMS and SBUV ozone satellite data.

CM-039

KOMHYR, W.D., R.D. GRASS, and R.K. Leonard. Calibration of primary standard Dobson spectrophotomter no. 83 and total ozone trends at Mauna Loa Observatory, Hawaii, and American Samoa, South Pacific. Ozone in the Atmosphere. Proceedings, Quadrennial Ozone Symposium 1988 and Tropospheric Ozone Workshop, Göttingen, FRG, August 8-13, 1988, R.D. Bojkov and P. Fabian, (eds.), A. Deepak, Hampton, Virginia, 85-87 (1989).

The long-term ozone measurement precision of Primary Standard Dobson Spectrophotometer no. 83 has been maintained to within an uncertainity of ±0.5% during 1962-1987. Total ozone data obtained at Mauna Loa Observatory (MLO) since 1963 and Samoa Observatory (SMO) since 1975 have been reprocessed on the scale of Dobson instrument no. 83. On average, total ozone increased at MLO during 1964-1974 at a rate of 0.37%/yr, but decreased during 1974-1987 at a rate of 0.35%/yr; at SMO, the ozone decrease rate measured during 1976-1987 was 0.40%/yr. Unusually low total ozone amounts were observed at SMO at the time in late 1986-early 1987 of the minimum in the tropical Quasibiennial Oscillation in ozone.

CM-040

KOMHYR, W.D., E.A. CROZER, J.A. LATHROP, and M.A. WINEY. ECC ozonesonde observations at South Pole, Antarctica, during 1989. NOAA DR ERL CMDL-5, 247 pp. (1990).

Atmospheric ozone vertical distributions, air temperature, and wind speed and wind direction data are presented for 60 balloon electrochemical concentration cell (ECC) ozonesonde soundings made at South Pole, Antarctica, in 1989.

CM-041

KOMHYR, W.D., J.A. LATHROP, and D.P. OPPERMAN. ECC ozonesonde and Umkehr observations during STOIC 1989. Digest of Topical Meeting on Optical Remote Sensing of the Atmosphere, 1990, Optical Society of America Washington, D.C., 4:441-444 (1990).

NOAA ECC ozonesonde and Dobson spectrophotometer Umkehr data obtained July 21-August 1, 1989, at Table Mountain, California during STOIC 1989 are compared with quasi-simultaneously obtained NASA Wallops Island ECC sonde data, Jet Propulsion Laboratory and Goddard Space Flight Center lidar ozone data, and Millitech Corporation microwave ozone data.

CM-042

KOMHYR, W.D., R.D. GRASS, R.D. Evans, and R.K Leonard. Results of international Dobson spectrophotometer and Brewer spectrometer calibrations, Arosa, Switzerland, 1986. Ozone in the Atmosphere. Proceedings, Quadrennial Ozone Symposium 1988 and Tropospheric Ozone Workshop, Göttingen, FRG, August 8-13, 1988, R.D. Bojkov and P. Fabian, (eds.), A. Deepak, Hampton, Virginia, 776-779 (1989).

An international comparison of Dobson spectrophotometer and Brewer spectrometers was conducted in Arosa, Switzerland, in August 1986. Countries participating with Dobson instruments were Belgium, Czechoslavakia, Denmark, Egypt, the Federal Repubic of Germany, France, the German Democratic Republic, Norway, Poland, Portugal, Spain, Switzerland, and the United States. The reference standard instrument for the comparisons was World Primary Sandard Dobson spectrophotometer no. 83 maintained by the United States. The mean difference in ozone measured by the 15 participating Dobson instruments relative to Dobson instrument no. 83, for observations in the air mass range 1.15-3.2, was -0.5 ± 1.5 (1s)%. Countries participating with Brewer spectrometers were Canada, Greece, and the Federal Republic of Germany. The Brewer instruments yielded ozone values lower on average than Dobson instrument no. 83 values by 0.3 ± 0.6 (1s)%.

CM-043

KOMHYR, W.D., S.J. OLTMANS, P.R. Franchois, W.F. Evans, and W.A. Matthews. The latitudinal distribution of ozone to 35 km altitude from ECC ozonesonde observations, 1985-1987. Ozone in the Atmosphere. Proceedings, Quadrennial Ozone Symposium 1988 and Tropospheric Ozone Workshop, Göttingen, FRG, August 8-13, 1988, R.D. Bojkov and P. Fabian, (eds.), A. Deepak, Hampton, Virginia, 147-150 (1989).

Electrochemical concentration cell (ECC) ozonesonde observations, made in recent years at nine stations whose locations range from the Arctic to Antarctica, have yielded a self-consistent ozone data base from which the latitudinal ozone distribution to 35 km altitude has been derived. Mean seasonal and annual ozonesonde profiles are presented, together with isopleths of ozone volume mixing ratios to 35 km altitude as a function of latitude. The data should be useful for comparison with model calculations of the global distribution of atmospheric ozone, for serving as a priori statistical information in deriving ozone vertical distributions from satellite and Umkehr observations, and for improving the satellite and Umkehr ozone inversion algorithms.

CM-044

KOMHYR, W.D., S.J. OLTMANS, R.D. GRASS, P.R. Franchois, and R.K Leonard. Changes in total ozone and ozone vertical distribution at South Pole, Antarctica, 1962-1987. Ozone in the Atmosphere. Proceedings, Quadrennial Ozone Symposium 1988 and Tropospheric Ozone Workshop, Göttingen, FRG, August 8-13, 1988, R.D. Bojkov and P. Fabian, (eds.), A. Deepak, Hampton, Virginia, 28-31 (1989).

Ozone profile measurements made at South Pole with Regener chemiluminescent ozonesondes in 1962-1965 and with ECC ozonesondes in 1967-1971 and 1986-1987 indicate a decrease in the magnitude of the primary ozone maxima and an increase in the maxima altitudes, with time, for all seasons. The most marked ozone reduction occurred in recent years during October months. A record low ozone amount of 127 DU was observed at South Pole in early October 1987. The 1986 and 1987 springtime ozone decrases at South Pole differed in magnitude as well as in the times of ozone recovery.

CM-045

KOMHYR, W.D., J. A. LATHROP, V. N. Arbuzova, V.U. Khattatov, V.I. Pilipenko, and V.V. Rudakov. ECC ozonesonde observations at Mirny, Antarctica, during 1989. NOAA DR ERL CMDL-4, 84 pp. (1990).

Atmospheric ozone vertical distributions, air temperature, and wind speed and direction data are presented for 24 balloon electrochemical concentration cell (ECC) ozonesonde soundings made at Mirny, Antarctica, in 1989.

CM-046

LANG, P.M., L.P. Steele, R.C. Martin, and K.A. Masarie. Atmospheric methane data for the period 1983-1985 from the NOAA/GMCC global cooperative flask sampling network. NOAA TM ERL CMDL-1, 90 pp. (1990).

This report presents details of relevant aspects of the NOAA/GMCC program to measure atmospheric methane concentrations through its global, cooperative, flask sampling network. These aspects include the history of the development of the program; details of the sampling network; the flasks and the flask sampling methods; the analytical instrumentation and methods; and the calibration gases and methods. The data from individual flask samples are tabulated, as are the monthly average methane concentrations.

CM-047

Liebmann, B., and H.H. Hendon. Synoptic-scale disturbances near the equator. Journal of Atmospheric Science 47:1463-1479 (1990).

A spectral analysis of winds analyzed and initialized at the European Centre for Medium-Range Weather Forecasts reveals an abundance of power in the 850 mb meridional wind along the equator with periods near four days. The power is mostly in the westward propagating component. Using high-pass filter data it is shown that the waves have westward phase and eastward group propagation relative to the mean wind. The longest wavelengths are found over the Pacific Ocean, while the shortest are found over the convectively variable regions of Indonesia, South America, and Africa. Mean phase speeds at 850 mb are positively correlated with the mean wind on the equator at 500 mb and below, and negatively correlated with the mean wind above that level. The effective advecting zonal wind of the disturbances seems to be the density weighted average of the lower troposphere. The structure of the disturbances bears resemblance to the expected structure of an equatorially trapped mixed Rossby-gravity wave over the central Pacific and Atlantic oceans, although the anomalies, while statistically significant, are extremely small. The outgoing longwave radiation (OLR) pattern is consistent with the flow field, suggesting that the waves are not merely a model artifact. Over the Atlantic there is a mode well defined by the zonal wind at the equator, but the OLR pattern is not consistent. Over the far western Pacific, there is evidence of meridional propagation from Northern Hemisphere midlatitudes. North of the equator there is meridional propagation at every longitude. The strongest disturbances are primarily confined to the lower half of the troposphere, but at many longitudes there is evidence of a weak first baroclinic-mode structure within the troposphere. North of the equator the structures are barotropic. Effective equivalent depths are estimated by comparing dispersion characteristics with mixed Rossby-gravity dispersion curves. Where the assumption of a mixed Rossby-gravity mode is believed to be valid, the equivalent depths are found empirically to lie between 1-60 m.

CM-048

Margitan, J.J., G.A. Brothers, E.V. Browell, D. Cariolle, M.T. Coffey, J.C. Farman, C.B. Farmer, G.L. Gregory, J.W. HARDER, D.J. Hofmann, W. Hypes, S. Ismail, R.O. Jakoubek, W. KOMHYR, S. Kooi, A.J. Krueger, J.C. Larsen, W. Mankin, M.P. McCormick, G.H. MOUNT, M.H. Proffitt, A.R. RAVISHANKARA, A.L. SCHMELTEKOPF, W.L. Starr, G.C. Toon, A. Torres, A.F. TUCK, A. Wahner, and I. Watterson. Intercomparison of ozone measurements over Antarctica. Journal of Geophysical Research 94(D14):16,557-16,569 (1989).

Measurements of the abundances of ozone over Antarctica in August and September 1987 obtained during the Airborne Antarctic Ozone Experiment are intercompared. These measurements of ozone concentrations and total column abundance were obtained by three satellite instruments, two IR and one UV column-measuring instruments aboard the DC-8, one in situ DC-8, and two in situ ER-2 instruments, an upward looking lidar aboard the DC-8, and ozonesondes from four sites in Antarctica. Given the natural variability of ozone in the Antarctic and the fact that the data were not truly coincident spatially and temporally, the intercomparison is suitable only for identifying gross disparities among the techniques, rather than confirming the accuracies as rigorously as is normally done in an intercomparison. This paper presents a summary of the ozone data, using the data and accuracies given by the individual investigators in the individual papers in this issue, without any attempt to critically review or evaluate the data. In general very good agreement (within about 10-20%, limited by natural variability) among the various techniques was found, with no systematic biases detected. These observations confirm the low ozone amounts reported in the Antarctic stratosphere.

CM-049

Matthews, W.A., W.D. KOMHYR, P. Franchois, and S. OLTMANS. Vertical distribution and variation in atmospheric ozone over Lauder, New Zealand. Ozone in the Atmosphere. Proceedings, Quadrennial Ozone Symposium 1988 and Tropospheric Ozone Workshop, Göttingen, FRG, August 8-13, 1988, R.D. Bojkov and P. Fabian, (eds.), A. Deepak, Hampton, Virginia, 132-135 (1989).

The establishment of the climatology of the vertical ozone distribution over Lauder, New Zealand (45°S) has been attempted by releasing ECC ozone sondes twice weekly through the Southern Hemisphere springs of 1986 and 1987 and at the rate of once per week for the intervening period. Data from this extended series of flights will be presented and discussed. A feature that is often present in the ozone profiles is a secondary peak just above the tropopause and this is attributed to the influence of the subtropical jet. In the spring of 1987, the ozone concentration appears to be less variable than in the spring of 1986 when on many occasions a "double dip" or "triple peak" phenomenon was observed. Examples of these and other features in the ozone profiles are given.

CM-050

McPeters, R.D., and W.D. KOMHYR. Long-term chanes in SBUV/TOMS relative to the world primary standard Dobson instrument. Ozone in the Atmosphere. Proceedings, Quadrennial Ozone Symposium 1988 and Tropospheric Ozone Workshop, Göttingen, FRG, August 8-13, 1988, R.D. Bojkov and P. Fabian, (eds.), A. Deepak, Hampton, Virginia, 265-267 (1989).

The SBUV and TOMS (solar backscattered ultraviolet and total ozone mapping spectrometer) instruments on Nimbus 7 have measured a decrease in total ozone between 1979 and 1986 of 5%, while the Dobson network reports only a 3% decrease during the same period, bringing the long-term calibration of SBUV/TOMS into question. We have examined the time dependence of the calibration by comparing ozone measured by TOMS and SBUV with that measured by Dobson instrument No. 83, which has been maintained since 1962 as a standard for total ozone. Measurements of AD pair ozone made with instrument No. 83 at Mauna Loa observatory in the summers of 1979, 1980, 1981, 1984, 1986, and 1987 were compared with coincident TOMS ozone measurements. The comparison shows that TOMS was stable relative to instrument No. 83 between 1979 and 1982, had decreased by 1% relative to instrument no. 83 by 1984, and had decreased by 3% by 1986 and 1987. A similar time dependence is seen when an ensemble of 41 Dobson stations throughout the world is compared with TOMS over the period 1979-1986. The most likely reason for the relative drift is that the diffuser plate, which is used by both SBUV and TOMS to measure solar flux, has suffered an uncorrected wavelength dependent degradation, with most of the degradation occurring between 1983 and 1986.

CM-051

OLTMANS, S.J. Water vapor profiles for Boulder, Colorado, and Pago Pago, American Samoa, during the period 1986-1989. NOAA DR ERL CMDL-3, 223 pp (1990).

Stratospheric water vapor profiles obtained from balloon-borne, chilled-mirror hygrometers are presented for Boulder, CO, and Pago Pago, American Samoa. The data are in tabulated and graphical form. The profiles for Boulder are a continuation of the monthly sounding program begun in 1981. The four soundings from Samoa were made as part of the SAGE II satellite correlative measurements program.

CM-052

OLTMANS, S.J., W.E. Raatz, and W.D. KOMHYR. On the transfer of stratospheric ozone into the troposphere near the north pole. Journal of Atmospheric Chemistry 9(1-3):245-253 (1989).

A series of nearly daily ozone vertical profiles obtained at station T-3 on Fletcher's Ice Island (~85°N, f90°W) during the period January-March 1971 shows several significant ozone intrusions into the troposphere. These intrusions are not only associated with enhanced ozone amounts in the stratosphere, but also require tropopause folding events to transport ozone into the troposphere. These folds in the Arctic tropopause appear to be capable of contributing significantly to the ozone budget of the Arctic troposphere during the late winter and spring seasons. The importance of tropopause folding for bringing ozone into the troposphere seen in the daily ozone profiles confirms the results found in the Arctic Gas and Aerosol Sampling Program aircraft flights.

CM-053

OLTMANS, S.J., W.D. KOMHYR, P.R. Franchois, and W.A. Matthews. Tropospheric ozone: Variations from surface and ECC ozonesonde observations. Ozone in the Atmosphere. Proceedings, Quadrennial Ozone Symposium 1988 and Tropospheric Ozone Workshop, Göttingen, FRG, August 8-13, 1988, R.D. Bojkov and P. Fabian, (eds.), A. Deepak, Hampton, Virginia, 539-543 (1989).

A self-consistent set of ozonesonde soundings from an eight-station network stretching from 75°N to 90°S confirms that there is more ozone in the NH troposphere than in the SH. There is a very strong enhancement at mid-tropospheric levels in ozone at Samoa (14°S) during the austral spring. This is also the period of enhanced tropospheric ozone over tropical South America and Africa. Fifteen years of surface measurements at the four Geophysical Monitoring for Climatic Change observatories show increasing ozone concentrations at the two NH sites (Barrow and Mauna Loa). At the two SH locations (Samoa and South Pole), ozone amounts have decreased dramatically (~2.0% yr^{-1}) during the austral summer (DJF) which is also the time of the seasonal minimum.

CM-054

OLTMANS, S.J., R.C. Schnell, P.J. Sheridan, R.E. Peterson, S.M. Li, J.W. Winchester, P.P. TANS, W.T. Sturges, J.D. Kahl, and L.A. Barrie. Seasonal surface ozone and filterable bromine relationship in the high Arctic. Atmospheric Environment 23(11):2431-2441 (1989).

Ozone and filterable bromine measurements in the high Arctic during the spring return of solar radiation suggest a rapid concurrent destruction of O_3 and conversion of gaseous to particulate Br. Multiyear observations show that this pattern is an annual feature of O_3 measured near the surface at Barrow, Alaska, and other Arctic locations. Aircraft measurements show low O_3 amounts and high filterable Br concentrations beneath the surface temperature inversion over ice throughout the Arctic in the spring. A wintertime build-up of the gaseous organic compound bromoform and a rapid depletion of bromoform in the spring may be a link between the episodic O_3 depletion events and the accompanying rise in filterable Br.

CM-055

OLTMANS, S.J., P.J. Sheridan, R.C. Schnell, R.E. Paterson, J.W. Winchester, L.A. Barrie, J.D. Kahl, and W.D. KOMHYR. Springtime surface ozone fluctuations at high Arctic latitudes and their possible relationship to atmospheric bromine. Ozone in the Atmosphere. Proceedings, Quadrennial Ozone Symposium 1988 and Tropospheric Ozone Workshop, Göttingen, FRG, August 8-13, 1988, R.D. Bojkov and P. Fabian, (eds.), A. Deepak, Hampton, Virginia, 498-501 (1989).

Ozone and filterable bromine measurements in the high Actic during the spring return of solar radiation suggest a rapid concurrent destruction of ozone and the conversion of gaseous to particulate bromine. Multi-year observations show that this pattern is an annual feature of ozone measured near the surface at Barrow, Alaska and other Arctic locations. Aircraft measurements show low ozone amounts and high filterable bromine concentrations beneath the surface temperature inversion over ice throughout the Arctic. A wintertime buildup of the gaseous organic compound bromoform and its rapid depletion in the spring may be a link between the episodic ozone depletion events and the concomitant rise in filterable bromine.

CM-056

Radke, L.F., C A. Brock, J.H. Lyons, P.V. Hobbs, and R.C. Schnell. Aerosol and lidar measurements of hazes in mid-latitude and polar airmasses. Atmospheric Environment 23(11):2417-1430 (1989).

Airborne lidar and in situ measurements of hazes were obtained in March 1986 during research flights from the East Coast of the United States to Baffin Island, Canada. Mid-latitude and polar airmasses, clearly separated by a frontal zone, displayed distinct differences in aerosol characteristics and in the vertical structure of aerosol layers. The data illustrate the differences between freshly polluted, mid-latitude air and clean and hazy polar air. Particle size spectra in the mid-latitude airmass contained distinct nucleation (0.01-0.1 μm diameter) and accumulation (0.1-1.0 μm diameter) modes, while in the polar airmass there was generally only an accumulation mode. The modal diameter of particles in the accumulation mode increased with increasing particle concentration in the polar airmass. Differences in the shapes of the particle size spectra measured in the two airmasses can be explained by differences in the sources and lifetimes of the particles. Hazes observed by a 1.064 μm wavelength lidar in the mid-latitude airmass were relatively diffuse, while those in the polar airmass appeared in multiple thin laminae. Measurements of the wind speed profile suggest that the multi-layered structure of the hazes in the polar airmass was due to the advection of thin, hazy regions into the generally clean polar airmass and by the extreme thermal stability of the lower troposphere.

CM-057

Rahn, K.A., D.H. Lowenthal, and J.M. HARRIS. Long-range transport of pollution aerosol from Asia and the Arctic to Okushiri Island, Japan. Atmospheric Environment 23(11):2597-2607 (1989).

An unbroken 6-month series of daily aerosol samples from Okusiri Island, Japan, was analyzed for trace elements and sulfate. Together with isobaric back-trajectories, the chemical data showed that distinct pulses of aerosol were observed from northeastern China, the Central U.S.S.R., and the Arctic. During winter, air frequently came vigorously from the W-NW. Long-range transport was prevalent, and the average aerosol resembled that of the Central U.S.S.R. During spring, circulation was weaker and more from the W-SW. Aerosol from Japan and China was more abundant. During winter, SO^{2}_{4} was apportioned roughly equally between the Central U.S.S.R. and China/Japan. In spring, contributions from the more-local China/Japan increased to about 2/3 of the total.

CM-058

Reinsel, G.C., G.C. Tiao, J.J. DELUISI, S. Basu, and K. Carriere. Trend analysis of aerosol-corrected Umkehr ozone profile data through 1987. Journal of Geophysical Research 94(D13):16373-16,386 (1989).

Trend analysis of stratospheric Umkehr ozone profile data from 10 stations over the period 1977-1987 is considered. Two different correction methods to adjust the Umkehr data measurements for errors caused by volcanic aerosols, the theoretical model-based corrections method of DeLuisi et al. (1989) and an empirical method based on use of a composite optical thickness series, are examined and compared. Linear trend models which also include the $F_{10.7}$ solar flux term to account for solar cycle variations in the Umkehr data were estimated for the Umkehr data at each station using both aerosol error correction methods. The trend and solar flux effect estimates are generally similar for both methods. The results indicate a significant overall negative trend, exclusive of trend variations associated with solar flux variations, of the order of -0.5% per year in Umkehr layers 7-9 over the period 1977-1987, and a significant positive solar cycle association in all layers 4-9, with the maximum solar effect estimated to occur in layer 9. A comparison between the solar backscattered ultraviolet (SBUV) monthly average ozone profile data near the 10 Umkehr stations and the corresponding Umkehr data corrected for aerosol errors is performed to investigate possible drifts, and linear drifts are estimated for the differences between SBUV and corrected Umkehr data at each station. The results show a substantial overall negative linear drift in SBUV data relative to corrected Umkehr data in layers 7-9, with estimated values of the drift of the order of -1.0% pr year for layers 8 and 9.

CM-059

Rosen, J.M., N.T. Kjome, and S.J. OLTMANS. Observations of backscatter, particle concentration and frost point in north polar vortex stratospheric clouds. Geophysical Research Letters 17(9):1271-1274 (1990).

Near-simultaneous soundings of backscatter, particle size distribution and frost point were obtained in north polar stratospheric clouds (PSCs) near the center of the vortex. The measured particle sizes and concentration in type I PSCs tend to confirm earlier predictions based on remotely sensed properties.

CM-060

Schnell, R.C., T.B. Watson, and B.A. BODHAINE. NOAA WP-3D instrumentation and flight operations on AGASP-II. Journal of Atmospheric Chemistry 9:3-16 (1989).

The second Arctic Gas and Aerosol Sampling Program (AGASP-II) was conducted across the non-Soviet Arctic in March and April 1986, to study the aerosol, gaseous, chemical, and optical properties of Arctic haze. One component of the program was supported with an instrumented NOAA WP-3D atmospheric research aircraft. Measurements of wind, temperature, ozone, water vapor, condensation nucleus concentration, and aerosol scattering extinction coefficient were used to determine the locations and properties of haze layers. The first three NOAA WP-3D research flights were conducted north of Barrow, Alaska, and over the Beaufort Sea northeast of Barter Island, Alaska. The next three sampled conditions in the high Arctic near Alert, Northwest Territories, Canada. All basic meteorological, gas, and aerosol systems are described. The WP-3D flight tracks and operations are presented.

CM-061

Sheridan, P.J. Analytical electron microscope studies of size-segregated particles collected during AGASP-II, Flights 201-203. Journal of Atmospheric Chemistry 9:267-282 (1989).

Cascade impactor samples were collected over the Alaskan Arctic during the first three research flights of AGASP-II. These samples were analyzed using analytical electron microscopy to determine the morphology mineralogy and elemental composition of individual particles. For analytical considerations, a typical impactor sample was run for approximately 20 minutes thus giving excellent time resolution of discrete events. Samples collected during flights 201 and 202 consisted of stratospheric aerosol and lower-altitude haze samples. Stratospheric samples were characterized by moderate loadings of H_2SO_4 droplets with relatively few particles of other types. Samples collected in tropospheric haze layers generally exhibited light-to-moderate particle loadings. H_2SO_4 was again the most prevalent species, with crustal and anthropogenic particles also observed. One sample taken over south-central Alaska near the end of flight 203 showed high concentrations of solid crustal particles with relatively little associated H_2SH_4. Giant particles larger than 5 μm were occasionally observed in this aerosol. The composition of this material closely matches that of bulk ash from the Mt. Augustine volcano, which erupted 9-13 days before collection of this sample. This brings forth the possibility that pockets of ash-rich aerosol existed over parts of south and central Alaska during the AGASP-II field mission. There is no evidence that these volcanic aerosols were present in the AGASP study area north of the Brooks Range.

CM-062

Sheridan, P.J. Analytical electron microscope analysis of aerosol sampled over White Sand Missile Range, New Mexico, July 10-14, 1989. Final report to the U.S. Army Atmospheric Sciences Laboratory, White Sands Missile Range, NM, 30 pp., (1989).

Size segregated aerosol samples collected over the White Sands Missile Range (WSMR), New Mexico, by aircraft in July 1989 were analyzed on a particle-by-particle basis using analytical electron microscopy. For fine fraction aerosols (<~1 μm diam), a dominant sulfate component was observed in all samples. These small (0.3-0.4 μm mean diam) sulfate particles were highly neutralized and were solid at the time of collection. Other particle types observed in the fine aerosol were soil dust of various compositions, composite sulfate particles, and carbonaceous (both combustion and non-combustion) particles. Coarse-fraction (super-μm) aerosol samples showed more types of particles than the fine fraction samples, but particle numbers were lower by several orders of magnitude. The two most common classes of particles in the super-μm aerosol were crustal dust and "reaction product" particles. Reaction project particles are characterized by a rounded, amorphous structure and are usually Ca-, Ca/Mg-, or Na-rich with little S. The precursors of these particles were probably soil- or marine-derived, and may have reacted with liquid water or aqueous H_2SO_4 droplets in the atmosphere. Larger sulfate particles were observed in these samples, along with composite sulfate particles, soot and non-combustion C-rich particles, marine salt, Fe-rich particles, and fly ash and other urban air pollution particles. The classes of particles described above for fine and coarse samples were found at every sampled altitude during the July flights. Analysis of aircraft and local radiosonde records indicate that the aircraft did not fly above the planetary boundary layer during the entire sampling portion of the mission. This explains the similarity of samples collected at very high and very low altitudes, in that a deep, well-mixed boundary layer was always being sampled. Winds during this mission were predominantly out of the south, often passing directly over the border cities of El Paso, Texas, and Ciudad Juarez, Mexico. This study suggests that the aerosol sampled at White Sands during July 1989 was influenced significantly by pollution emissions from these urban areas. The differences between aerosols collected in May 1989 and those reported on in this study highlight the fact that during different seasons and/or flow patterns, aerosol composition may vary greatly in the White Sands area.

CM-063

Sheridan, P.J. Characterization of size segregated particles collected over Alaska and the Canadian high Arctic, AGASP-II Flights 204-206. Atmospheric Environment 23(11):2371-2386 (1989).

Ten aircraft-collected cascade impactor samples from the North American Arctic were analyzed using analytical electron microscopy. Morphological, mineralogical, and elemental information were obtained from individual particles, as well as compositional data and size distribution estimates of the bulk aerosol. Categorization of carbonaceous material into organic-type and combustion-type carbon particles was performed in this study. This was accomplished through the use of a new ulta-thin window X-ray spectrometer, which can directly detect carbon X-rays emitted from particles and through interpretation of morphological and electron diffraction data. Verification of graphite as a specific carbon mineral phase present in Arctic soot particles was performed in this manner. Several classes of particles were present in most of the aerosol samples and size fractions. These included liquid H_2SO_4 droplets, which were always present in the highest numbers, and crustal-type and composite SO^{2-}_4 particles. A small fraction (0-30%) of a random sampling of SO^{2-}_4 particles from all impactor stages were found to contain detectable nitrogen, suggesting that partial neutralization by NH_3 may have occurred in this minority of the SO^{2-}_4 droplets. Particles rich in non-combustion carbon and thought to be composed of organic material were also observed in most samples. Haze samples collected off the coast of Alert, NWT, show moderate loadings of H_2SO_4 droplets. Judging from these loadings and those from higher-altitude samples, ambient aerosol particle concentrations must have been considerably higher in the haze. The extent to which local activity at Alert has influenced these haze samples is not known although a

major contribution is not expected. Stratospheric samples did not contain several classes of particles thought to have major anthropogenic source inputs to the Arctic, such as black carbon and coal-fired combustion spheres. The lightest particle loadings in any samples were collected in the upper troposphere near the tropopause where condensation nuclei counts during sampling fell to as low as 10 cm^{-3}.

CM-064

Sheridan, P.J., and W.H. Zoller. Elemental composition of particulate material samples from the Arctic haze aerosol. Journal of Atmospheric Chemistry 9.363-381 (1989).

Thirty-six aerosol filter samples collected in tropospheric Arctic haze layers, in the stratosphere, and in the marine boundary layer during the 1983 Arctic Gas an Aerosol Sampling Program were analyzed for trace elements using instrumental neutron activation analysis. Average crustal dust concentrations were 540 ng/m^3 and 330 ng/m^3 for samples collected in Arctic haze over the North American and Norwegian Arctic, respectively. An average marine salt concentration of 120 ng/m^3 was obtained for haze samples collected above the marine boundary layer on both sides of the Arctic. Meteorological and wind trajectory information were used to identify specific haze transport pathways, which brought relatively unmixed aerosol from the central Soviet Union into the AGASP sampling areas. Results from individual filters collected within these transport zones are discussed, with emphasis on certain trace metal ratios which have been proposed by other researchers as discriminators of aerosols from different source regions. Our aircraft-collected data are compared with previously-collected ground-based measurements and show reasonably good agreement for most trace elements and ratios. Specifically, we have determined the As/Sb ratio tracer, named by other researchers as the most effective elemental discriminator of aerosol from the central Soviet Union, to be approximately 5-6. This relatively high tracer value is consistent with previous groundbased findings. A significantly lower V/Sb ratio was observed throughout this study, possibly indicating a change in the source signature.

CM-065

Sievering, H., P.J. Sheridan, and R.C. Schnell. Short Communication. Size distribution of large aerosol particles during AGASP-II:absence of St. Augustine eruptive particles in the Alaskan Arctic. Atmospheric Environment 23(11):2495-2499 (1989).

Number distribution data for 0.1-45 μm diameter aerosol were obtained using optical counting and sizing probes flown over the Alaskan Arctic during the second Arctic Gas and Aerosol Sampling Program (AGASP-II), flights 201-203. Due to noise present in the lowest size channels of the optical probes, estimates of the H_2SO_4 component of Arctic haze were not attempted. Large particle (>0.5 μ m diameter) results are presented here. Large particle number and volume concentration were determined along with estimated mass, which was generally ~0.1 $\mu g\ m^{-3}$. Lognormal fitting to >0.3 $\mu g\ m^{-3}$ mass loading size-distributed aerosol data produced a means for comparing volume geometric median diameters (VGMD) for these higher-mass time intervals. These VGMDs showed that solid crustal particles previously observed during AGASP-II had VGMDs in the 1.2-1.6 μm range and that the shape of these fitted lognormal distributions was essentially constant. This result suggests very-long-range transport from a distant crustal source and, in conjunction with aerosol physical and chemical characterization data, argues against the presence of the Mt. Augustine eruptive particles during AGASP-II Alaskan Arctic sampling.

CM-066

Stone, R.S., E.G. DUTTON, and J.J. DELUISI. Surface indicator and temperature variation associated with cloudiness at the South Pole. Antarctic Journal 24(5):230-232 (1990).

No abstract.

CM-067

Stone, R.S., G.L. Stephens, C.M.R. Platt, and S. Banks. The remote sensing of thin cirrus cloud using satellite, lidar and radiative transfer theory. Journal of Applied Meteorology 29(5):353-366 (1990).

The problem of retrieving cirrus cloud optical depth from radiance measurements made by instruments aboard operational meteorological satellites is addressed. A method is proposed that exploits the relationship between observed differences in the near infrared (NIR) and infrared (IR) window radiances (expressed in terms of brightness temperature differences ΔT) and the optical depth of the cloud. The approach designed to test this method relies on the simultaneous collection of ground-based lidar and infrared radiometric (LIRAD) data, radiosonde data, and biospectral satellite images. Two case studies are described for which independent estimates of satellite pixel and coincident time-averaged LIRAD optical depths are compared with radiative transfer calculations made for hypothetical clouds characterized by distributions of spherical ice particles. Such comparative analyses yield information about cloud microphysics and enable the selection of representative theoretical relationships between estimates of cloud optical depth and observed spectral differences. A third case demonstrates the potential use of this split window technique to estimate cirrus cloud optical depth when only operational data is available. In the first two cases, it was found that the LIRAD-derived optical depths agree to within 70% of the satellite estimates for optical depths greater than about 0.3, and that the differences tend to be systematic. Larger discrepancies are noted for thinner clouds, however, indicating inaccuracies in one or the other, or possibly both of these methods when applied to very thin layers. Another possible cause for these large discrepancies is the potential ambiguity in comparing the spatially averaged satellite data with time-averaged LIRAD data if physical changes in cloud structure occur during the course of the experiment. We also found that, in all cases, the observed spectral differences (NIR-IR) agree reasonably well with model simulations if the clouds are assumed to be composed of distributions of large spherical ice particles having effective radii in the 32-64 μm range.

CM-068

Sturges, W.T., and L.A. Barrie. Stable lead isotope ratios in arctic aerosols: evidence for the origin of arctic air pollution. Atmospheric Environment 23(11):2513-2519 (1989).

The isotopic composition of aerosol lead in the polar region potentially contains information on the origin of Arctic pollution which will complement that from meteorological and trace elemental composition studies. Weekly samples of atmospheric aerosols were collected at three locations in the Canadian Arctic from mid-1983 to mid-1984. They were analyzed for elemental composition and stable lead isotope ratios (Pb 206/207). High crustal enrichment factors confirmed that the majority of samples contained lead of anthropogenic origin. Pb 206/207 ratios were very uniform over time and between sites, suggesting a common origin of lead pollution in the Canadian Arctic. The mean isotope ratios at the Alert and Mould Bay stations were 1.160 ± 0.010 and 1.161 ± 0.006, respectively (samples from a third site at Igloolik were evidently contaminated by local sources). A small number of samples from Spitsbergen, taken during flow predominantly out of the northern U.S.S.R., were found to have a similar mean Pb 206/207 ratio of 1.154 ± 0.006. From published lead isotope analyses of Soviet lead-bearing ores, we would expect a mean isotope ratio in industrial and vehicular emissions in the U.S.S.R. of around 1.158. Contributions to Arctic lead pollution from the U.S. and western Canadian sources can probably be ruled out, as they have significantly higher Pb 206/207 ratios. Similarly, emissions from northern Canadian and Kola Peninsula smelters can be disregarded, as they appear to have low isotope ratios. Eastern Canadian automotive lead aerosol contained only marginally lower Pb 206/207 ratios than in the Arctic, but meteorological studies argue against this region being a major source area for Arctic pollution. Scant European data suggest that European Pb emissions generally have lower isotope ratios than the Arctic samples. However, more data in Eurasia are needed before apportionments of Arctic Pb between sources within the region can be made.

CM- 069

TANS, P.P., I.Y. Fung, and T. Takahashi. Observational constraints on the global atmospheric CO_2 budget. Science 247:1431-1438 (1990).

Observed atmospheric concentrations of CO_2 and data on the partial pressures of CO_2 in surface ocean waters are combined to identify globally significant sources and sinks of CO_2. The atmospheric data are compared with boundary layer concentrations calculated with the transport fields generated by a general circulation model (GCM) for specified source-sink distributions. In the model the observed north-south atmospheric concentration gradient can be maintained only if sinks for CO_2 are greater in the Northern than in the Southern Hemisphere. The observed differences between the partial pressure of CO_2 (pCO_2) in the surface waters of the Northern Hemisphere and the atmosphere are too small for the oceans to be the major sink of fossil fuel CO_2. Therefore, a large fraction of the CO_2 is apparently absorbed on the continents by terrstrial ecosystems.

CM-070

TANS, P.P., K.W. THONING, W.P. ELLIOT, and T.P. CONWAY. Error estimates of background atmospheric CO_2 patterns from weekly flask samples. Journal of Geophysical Research 95:14,063-14,070 (1990).

The precision and accuracy of trends and seasonal cycles of CO_2, as determined from grab samples, was investigated. First, the statistical aspects of infrequent (weekly) sampling were studied by simulating, via a partially random procedure, parallel time series of CO_2 flask samples. These simulated flask series were compared to the continuous analyzer records from which they had been derived. The second approach to studying the uncertainties of flask records was to compare real flask results with simultaneous hourly mean concentrations of the in situ analyzers at the GMCC observatories at Point Barrow, Mauna Loa, Samoa, and the South Pole. The latter comparisons emphasized experimental, rather than statistical, errors. The uncertainties and sampling biases depend on the site and on the period of averaging. For monthly means the uncertainty varies from 0.2 to 0.6 ppm (one standard deviation, parts per million by volume), being largest for Barrow. Sampling biases for monthly means at Barrow and Mauna Loa are significant, up to 0.5 ppm. Experimental errors are the dominant error source for annual averages, and spurious interannual variations can be up to 0.4 ppm.

CM-071

Taylor, J.A. A stochastic Lagrangian atmospheric transport model to determine global CO_2 sources and sinks-a preliminary discussion. Tellus 41B:272-285 (1989).

A stochastic Lagrangian model describing the global tropospheric distribution of CO_2 is developed. Available source and sink terms are incorporated in the model. Advection terms are derived from the European Centre for Medium Range Weather Forecasting (ECMWF) analyzed grids. Statistics for the variation in the advective terms are derived and incorporated in the model from the ECMWF data base. Model output is compared with CO_2 observations obtained from the National Oceanic and Atmospheric Administration (NOAA) Geophysical Monitoring for Climatic Change (GMCC) program. Model estimates of the yearly averaged latitudinal gradient of CO_2 concentration match the observed CO_2 concentrations except over the southern oceans. A biospheric growing season net flux (GSNF) of 6.5 GtC was found, from model simulations, to explain the observed seasonal cycle in CO_2 concentrations. This value of the GSNF lies within the bounds of previous estimates. The intensity of the biospheric fluxes above 60°N, oceanic fluxes below 45°S and model vertical transport warrant further investigation

CM-072

WATERMAN, L.S., DW. NELSON, W.D. KOMHYR, T.B. HARRIS, K.W. Thoning, and P.P. TANS. Atmospheric carbon dioxide measurements at Cape Matatula, American Samoa, 1976-1987. Journal of Geophysical Research 95(D12):14,817-14,829 (1989).

The U.S. National Oceanic and Atmospheric Administration (NOAA) has operated a program to continuously monitor atmospheric CO_2 at Cape Matatula, American Samoa, since January 1976. This paper describes the basic operational program and reports the data through 1987. Data sets are derived from hourly means which have been selected to represent baseline conditions. All hourly mean CO_2 values (with flags indicating data selection status) are archived at NOAA's Geophysical Monitoring for Climatic Change (GMCC) laboratory in Boulder, Colorado; at the Carbon Dioxide Information and Analysis Centre in Oak Ridge, Tennessee; and in the microfiche version of this paper. The record from the in-situ analyzer is compared with that of flask samples obtained in various ways. The overall 12-year record shows an average increase of 1.44 parts per million by volume per year. This increase amounts to 61% of the carbon dioxide emitted into the atmosphere by fossil fuel combustion during this period. The record is also characterized by the lack of a prominent seasonal cycle. The CO_2 concentrations for the first half of each year are always more variable than the second 6 months, when the wind flow is dominated by strong southeasterly trades. The interannual variability of the CO_2 growth rate correlates very well with that observed at other GMCC sites.

CM-073

WEICKMANN, K.M., and S.J.S. Khalsa. The shift of convection from the Indian Ocean to the Western Pacific Ocean during a 30-60 day oscillation. Monthly Weather Review 118:964-978 (1990).

A strong 30-60 day oscillation during November/December 1981 is studied using analyzed winds from the National Meteorological Center, outgoing longwave radiation, and satellite low-level moisture data. The outgoing longwave radiation and 150 mb velocity potential for five adjacent events are also examined. Consistent features include the slow (5 m s^{-1}) propagation of convective energy over the Indian Ocean-western Pacific Ocean and the fast (15 m s^{-1}) propagation of 150 mb tropical velocity potential in regions remote from the oceanic warm pool. The individual events have characteristics of the seasonal and anomalous base state within which they are embedded. For the November/December 1981 event, we concentrate on the details of the shift of convection from the eastern Indian Ocean to the western Pacific Ocean. An intense cold surge and accompanying convective increase near 110°E precede the shift east by about 12 days. The regional 150 mb circulation responds to the enhanced convection with an intensified anticyclone over southeast China and a downstream trough over the subtropical western Pacific. At low levels, the 850 mb subtropical high over the North Pacific strengthens and amplifies as a wave train emanates from the region of the downstream upper-level trough. A surge of central Pacific Ocean trades accompanies these developments. In equatorial regions a component of convection moves east accompanied by low-level westerly winds to near 170°E. Strong 850 mb convergence occurs between the trade surge and the westerly winds favoring low-level moisture increases over the western Pacific. The convection then intensifies near 150°E and weakens near 110°E, eventually forcing a transition in the regional anomalous circulation (i.e., a 150 mb cyclone over southeast China and anticyclone over the western Pacific). An important feature of the transition appears to be the initiation of convection near the node of the existing anomalous 150 mb circulation by an eastward moving equatorial transient. Otherwise, convection occurs primarily in regions of upper-level easterlies associated with subtropical anticyclones. Such structures appear to represent quasi-stationary regimes that can last for 10-20 days. These regimes, in conjunction with the rapid eastward shift of convection, give rise to a large standing component in the outgoing longwave radiation and 150 mb stramfunction during the November/December 1981 event and in other 30-60 day oscillation events.

CM-074

Wolter, K. Trimmed COADS-problems and solutions. Proceedings, 14th Climate Diagnostics Workshop, La Jolla, California, October 1989, National Weather Service, Washington, DC, 228-233 (1989).

Extended abstract.

CM-075

Wolter, K., S. Hastenrath. Annual cycle and long-term trends of circulation and climate variability over the tropical oceans. Journal of Climate 2:1329-1351 (1989).

Trends in the large-scale circulation and seasonal characteristics of climate variability are investigated based on ship observations of sea level pressure, zonal and meridional wind components, sea surface temperature, and cloudiness, and land station records during 1948-83. Cluster analysis captures such features as the surface pressure dipoles associated with the Southern Oscillation, the subtropical region of influence of the North Atlantic Oscillation, preferred areas of surges in the North Atlantic trades and monsoon over the Indian Ocean, equatorial warm water regions with El Niño-type behavior in the eastern Pacific and Atlantic, and typical centers of interannual cloudiness variations associated with trade wind variations and the ITCZ. Long-term trends are examined in terms of internal consistency between elements, between ship and land records, and in regard to the possible effect of shifts in observational practices. Most prominent are the following trends over the 1948-83 period: (i) increasing prevalence of the negative Southern Oscillation phase (characterized by anomalously low/high pressure at Tahiti/Darwin) accompanying the increas of El Niño occurrences; (ii) in boreal summer a southward shift of the Atlantic near-equatorial low-pressure trough and embedded confluence zone and warming/cooling of surface waters to the south/north of the Equator, paralleling the progressive aggravation of drought in Subsaharan Africa; (iii) likewise in boreal summer a more easterly position of both the North and South Atlantic highs which together with (ii) connotes a reduced annual cycle of circulation in the tropical Atlantic sector, commensurate with the increasing prevalence of the negative SO mode: (iv) modulation of the annual cycle of circulation and rainfall regime over the western equatorial Atlantic, involving a somewhat earlier occurrence of the rainy season peak in Northeast Brazil; and (v) warming in the Indian Ocean.

CM-076

Zhou, M., S. Yang, F.P. PARUNGO, and J.M. HARRIS. Chemistry of marine aerosols over the western Pacific Ocean. Journal of Geophysical Research 95(D2):1779-1787 (1990).

During the first cruise operated by the United States of America and the People's Republic of China cooperative program, from December 12, 1985, to February 21, 1986, aerosol samples were collected with a KA-200 Anderson cascade impactor and a KB-120 sampler. Neutron activiation analysis was used to determine the elemental composition of the aerosols. Maximum mass concentrations of sea-salt elements (Na, Cl, and Br) were found in the size range 3.3-4.7 μm. The "bulk" enrichment factor for Cl in aerosols, relative to Na in seawater, was close to unity, but a very pronounced depletion was found for Br. The enrichment factor for Cl in different size ranges decreased with increasing particle size and for Br had a U-shaped curve. The size distributions for Fe, Al, and Sc over the remote ocean and over the ocean area close to the Asian continent were quite different. Aerosols over the western Pacific showed significant enrichment of Sb and Se, relative to Fe. Some characteristics of marine aerosols are discussed as they relate to long-range transport of crustal elements and pollution elements from the Asian continent to the western Pacific.

Addendum

CM-077

ELKINS, J.E., T.M. THOMPSON, B.D. Hall, K.B. Egan, and J.H. Butler. NOAA/GMCC halocarbons and nitrous oxide measurements at the South Pole. Antarctic Journal 23(5), 176-177 (1988).

No abstract.

CM-078

Hansen, A.D.A., B.A. BODHAINE, E.G. DUTTON, and R.C. Schnell, Aerosol black carbon measurement at the South Pole: Initial results. Geophysical Research Letters 15(11):193-1196 (1988).

In December 1986 an aethalometer was installed at the NOAA/GMCC South Pole Observatory to measure concentrations of the combustion effluent tracer species aerosol black carbon (BC) with a time resolution of one hour. We present data covering a 1-yr period from December 1986 through November 1987. The hourly data show infrequent events in which the concentrations increased greatly for periods of a few hours. We attribute these events to local contamination and identified them as such in the database. The remaining background data then yield daily average BC concentrations generally ranging from 50 pg m^{-3} to 5 ng m^{-3}, with a minimum in the early austral winter. The results imply long-range transport of this aerosol species, and suggest a minimum value of the order of 10 pg m^{-3} for its global background concentration.

CM-079

Karl, T.R., J.D. Tarpley, R.G. Quayle, H.F. DIAZ, D.A. Robinson, and R.S. Bradley. The recent climate record: What it can and cannot tell us. Reviews of Geophysics 27(3):405-430 (1989).

While a great deal of climate data have been gathered over the past hundred years, there remains a number of problems limiting our ability to fully utilize these data in reconstructing the climate of the past century. This is particularly true for research demanding high precision and/or detailed local or regional-scale climate analyses. In this review we consider our ability to quantify climate change with respect to near-surface air temperature (measured 1.25-2 m above ground), sea surface temperature, precipitation, snow cover, sea ice, and vegetation measured from space and the Earth's surface. Among the data issues we discuss are calibration, observing practices, urbanization, station changes, data representativeness, data access, and areal coverage. The diversity of measurements over the past century and the new monitoring system being introduced via space-based and surface-based platforms offer an unparalleled opportunity for global moitoring; but to quantify climate change, we must tackle such issues as changing retrieval algoriths, relatively short periods of record, satellite Earth location precision, incompatibility with previous conventional historical observations, calibration, and potentially overwhelming data volumes. A new specialty within the climate field is beginning to emerge to address these problems. Despite the litany of problems the instrumented climate record can tell us a great deal about the spatial distribution and secular trends in temperature and precipiation over many areas of the world. In the future a blend of many data types and observing systems will be necessary to better quantify climate change. These large data sets will have to be made accessible to scientists in such a way that allows them an opportunity to check the veracity of their hypotheses and predictions regarding climate change.

CM-080

Steele, L.P., T.J. CONWAY, L.S. WATERMAN, and P.M. Lang, The NOAA/GMCC measurements of CH_4 and CO_2 from flask air samples collected at Cape Grim. In Baseline Atmospheric Program (Australia) 1987. B.W. Forgan and G.P. Ayers (eds.). Department of Administrative Services, Bureau of Meteorology, CSIRO, Aspendale, Australia, 48-50 (1989).

No abstract.

CM-081

Wolter, K., S.J. Lubker, and S.D. WOODRUFF, Trimming-a potential error source in COADS. Tropical Ocean-Atmosphere Newsletter 51:4-7 (1989).

No abstract.

FORECAST SYSTEMS LABORATORY

FS-001

Albers, S.C. A severe weather forecast scheme incorporating mesoscale analyses. Preprints, 12th Conference on Weather Analysis and Forecasting, Monterey, California, October 2-6, 1989. American Meteorological Society, Boston, 242-246 (1989).

No abstract.

FS-002

AUGUSTINE, J.A., E.I. TOLLERUD, and B.D. JAMISON. Distributions and Other General Characteristics of Mesoscale Convective Systems During 1986 as Determined from GOES Infrared Imagery. Preprints, 12th Conference on Weather Analysis and Forecasting, Monterey, California, October 2-6, 1989. American Meteorological Society, Boston, 437-442 (1989).

No abstract.

FS-003

BARNES, S.L. and B.R. COLMAN. Quasi-Geostrophic Diagnosis of Tropopause Folding Associated with Extratropical Cyclone Development. Preprints, 12th Conference on Weather Analysis and Forecasting, Monterey, California, October 2-6, 1989. American Meteorological Society, Boston, 247-252 (1989).

No abstract.

FS-004

Birkenheuer, D. A local-scale VAS/profiler precipitable water analysis. Preprints, 12th Conference on Weather Analysis and Forecasting, Monterey, California, October 2-6, 1989. American Meteorological Society, Boston, 432-436 (1989).

No abstract.

FS-005

Birkenheuer, D. and D. Kim. Direct use of GOES radiance data in mesoscale data assimilation. Preprints, 5th Conference on Satellite Meteorology and Oceanography, London, England, September 3-7, 1990. American Meteorological Society, Boston, 334-338 (1990).

No abstract.

FS-006

BROWN, J.M. Synoptic Evolution, Upstream Stratification and Wind Profile Associated with a Severe Windstorm in Boulder, Colorado. Proceedings, 5th Conference on Mountain Meteorology, Boulder, Colorado, June 25-29, 1990, 66-67 (1990).

No abstract.

FS-007

Brown, T.J. and J.A. Flueck. Exploratory linear modeling of El Niño activity. Preprints, 11th Conference on Probability and Statistics, Monterey, California, October 1-5, 1990. American Meteorological Society, Boston, 244-248 (1990).

No abstract.

FS-008

CARACENA, F. and A. Marroquin. The Use of a Gridless Analysis Scheme in Complex, Diagnostic Calculations. World Meteorological Organization, International Symposium on Assimilation of Observations in Meteorology and Oceanography. Clermont-Ferrand, France, July 7-13, 1990, 566-571 (1990).

No abstract.

FS-009

COLMAN, B.R. Concerning the Need For an Effective Transfer of New Mesoscale Understanding to the Operational Community. Preprints, Third Workshop on Operational Meteorology, Montreal, Quebec, Canada, May 1-4, 1990, pp. 381-383 (1990).

The transfer of new understanding of the atmosphere to the operational community is discussed. It is argued that historically this transfer has, for the most part, been accomplished by the development of more accurate NWP and statistical guidance at national centers. A discussion of phenomenological research leads to a suggestion that there could be a more effective way for this transfer to occur. Namely, as new phenomena are observed and understood, there could be an effort by the research community to work with the operational community to develop physically consistent conceptual models that can be used by the field prior to the implementation of successful mesoscale NWP. This would assure the optimal utilization of new data sources from their inception.

FS-010

COLMAN, B.R. Mesoscale Analysis of an Upslope Snowstorm in Colorado. Preprints, 12th Conference on Weather Analysis and Forecasting, Monterey, California, October 2-6, 1989. American Meteorological Society, Boston, 372-377 (1989).

No abstract.

FS-011

COLMAN, B.R. The Influence of Barrier Jets on Local Snowfall Distribution. Preprints, Third Workshop on Operational Meteorology, Montreal, Quebec, Canada, May 1-4, 1990, pp. 325-330 (1990).

The influence of blocked, low-level, cold air on the mesoscale distribution of snowfall is presented. An existing conceptual model for cold-air damming in northeast Colorado is presented that requires a quasi-stationary, surface-convergence line; heavy snow is expected near this line as moist air is displaced upward over the cold air. Data collected during a winter-weather experiment in January 1989 are presented that suggest the surface-convergence line is not required and only represents one variation of this blocking phenomenon. It is suggested that the two extremes are (1) a nearly stagnant, local, cold pool with a stationary leading edge that has a characteristic density current structure, and (2) a well developed barrier jet with no stationary surface boundary and steeply sloped interface.

FS-012

COLMAN, B.R. Thunderstorms Above Frontal Surfaces in Environments Without Positive CAPE. Part 1. A Climatology. Monthly Weather Review, 118(5):1103-1121 (1990).

The first of two papers describing thunderstorms that occur above frontal surfaces, frequently in environments without positive convective available potential energy (CAPE), focuses on the climatology of such storms for the conterminous United States. The data set used consists of 1,093 observations made over a 4-year period. The events were selected using conventional network data and a set of criteria that eliminated thunderstorms rooted in the boundary layer. A composite of the data set shows that the typical "elevated" thunderstorm occurs northeast of an associated surface low-pressure center, and north of a surface warm front in a region with northeasterly surface winds. The planetary boundary layer is generally very stable as determined by comparisons with both the 50-kPa and 85-kPa air. The thunderstorms are usually found in the left exit region of a low-level wind maximum (an area of horizontal deformation). The large-scale environment is strongly baroclinic with large vertical wind shear and warm advection. Several of the identified characteristics suggest that frequently elevated thunderstorms are the result of physical mechanisms different from those fundamental to surface-based thunderstorms. The most striking of these is that for elevated thunderstorms there is generally very little, if any, positive CAPE in the environment, as the atmosphere is slightly more stable than moist adiabatic above the frontal inversion. The annual frequency distribution of elevated thunderstorms is bimodal, with a primary peak in April and a secondary peak in September. The events are concentrated in an area extending northward from the central Gulf Coast along the Mississippi River Valley. The data further show that nearly all winter-season (December through February) thunderstorms east of the Rocky Mountains are of the elevated type. The primary exception involves those over the Florida Peninsula, where surface-based convection persists throughout the year. Most of the winter-season elevated thunderstorms occur near the Gulf Coast downstream from migrating cyclones.

FS-013

COLMAN, B.R. Thunderstorms Above Frontal Surfaces in Environments Without Positive CAPE. Part 2. Organization and Instability Mechanisms. Monthly Weather Review, 118(5):1123-1144 (1990).

The second of two papers describing thunderstorms that occur above frontal surfaces, frequently in environments without positive convective available potential energy (CAPE), focuses on an impressive outbreak of elevated thunderstorms during AVE-SESAME I. It is shown that the thunderstorms occurred in three convective impulses, each of which developed in the warm sector before propagating onto the frontal surface; subsequent thunderstorms developed over the frontal surface. While in the warm sector, the convection was supported by an extremely unstable boundary layer. However, this convective energy quickly diminished above the frontal surface and thunderstorms continued and developed for many hours in an essentially stable hydrostatic environment. During the lifetime of these impulses, mesoscale

updrafts developed and moved with the convective areas, maintaining nearly steady-state systems with strong low-level inflow. The environment was found to be symmetrically neutral in the region of the inflow. Numerous pressure waves were observed in association with the elevated thunderstorms, yet these features were evidently not important in the triggering of the storms. An investigation of a convective band that formed above the frontal surface revealed that the development probably took place in two steps. Initially, high Re air overlying the frontal inversion was stable to vertical displacements, but inertially unstable. Then, along the instantaneous path of the unstable parcel, the thermodynamic structure changed, the parcel became gravitationally unstable, and upright convection resulted.

FS-014

Dunn, L.B. Mesoscale forecasting on DAR^{3}E tornadoes and other convection. Preprints, 12th Conference on Weather Analysis and Forecasting, Monterey, California, October 2-6, 1989. American Meteorological Society, Boston, 63-67 (1989).

No abstract.

FS-015

Dunn, L.B. Reply. Weather and Forecasting, 4:571-572 (1989).

No abstract.

FS-016

Flueck, J.A. and T.J. Brown. A study of possible solar-weather relations. 11th Conference on Probability and Statistics in Atmospheric Sciences, Monterey, California, October 1-5, 1989. American Meteorological Society, Boston, 325-333 (1989).

No abstract.

FS-017

GRIFFITH, C.G. Skill Scores of Satellite-Estimated Summertime Rainfall. Preprints, 11th Conference on Probability and Statistics, Monterey, California, October 1-5, 1989. American Meteorological Society, Boston, 144-149 (1989).

No abstract.

FS-018

GROTE, U.H. Real-time meteorological display on PROFS PC-based workstation. Proceedings, Society of Photo Optical Engineering (SPIE) Conference on Digital Image Processing and Visual Communications Technologies in the Earth and Atmospheric Sciences, Orlando, Florida, April 18-19, 1990. SPIE, Bellingham, Washington, Vol. 1301, 9 pp. (1990).

The acquisition and real-time analysis of comprehensive, high resolution meteorological data sets require considerable processing power. Each data source (such as radar, satellite and observing networks) requires unique processing to acquire the data, control quality, and convert the data into a user-acceptable form. To rapidly present these data for display at a workstation, much of the data are routinely converted into display-ready form and stored on the workstation disk. The PROFS PC-based workstation allows the forecast and research meteorologist to rapidly manipulate the displays and also access the raw data for custom processing. Although the workstation has been optimized for real-time response, the software is being extended to also allow some review and perusal of recorded data.

FS-019

Heideman, K.F. Evaluation of PROFS 1987 convective weather forecasts. Preprints, 11th Conference on Probability and Statistics in Atmospheric Sciences, Monterey, California, October 1-5, 1989. American Meteorological Society, Boston, 156-160 (1989).

No abstract.

FS-020

Hillger, D.W., J.S. SNOOK, and J.F.W. Purdom. A case study analysis of clustering applied to VAS measurements. Preprints, 5th Conference on Satellite Meteorology and Oceanography, London, England, September 3-7, 1990. American Meteorological Society, Boston, 354-359 (1990).

No abstract.

best copy available

FS-021

Jackson, M.E. The use of local variational analyses to derive short-term mesoscale severe weather probabilities. Preprints, 12th Conference on Weather Analysis and Forecasting, Monterey, California, October 2-6, 1989. American Meteorological Society, Boston, 231-235 (1989).

No abstract.

FS-022

Kelsch, M. and D.C. WALKER. Radar-derived rainfall and flash flood assessment with NEXRAD. Preprints, 12th Conference on Weather Analysis and Forecasting, Monterey, California, October 2-6, 1989. American Meteorological Society, Boston, 401-406 (1989).

No abstract.

FS-023

Kim, D. and D. Birkenheuer. Thickness assimilation using VAS radiance data. Proceedings, International Symposium of Assimilation of Observations in Meteorology and Oceanography, Clermont-Ferrand, France, July 9-13, 1990. World Meteorological Organization, 495-500 (1989).

No abstract.

FS-024

Marroquin, A. and J.M. BROWN. Diagnosis of NGM Performance for Spring Storms Over the Western United States. Preprints, 12th Conference on Weather Analysis and Forecasting, Monterey, California, October 2-6, 1989. American Meteorological Society, Boston, 617-622 (1989).

No abstract.

FS-025

Marroquin, A. and J.M. BROWN. Structure and Evolution of an Inverted Trough From Simulations with the Nested Grid Model. Paper presented at the Fourth Conference on Mesoscale Processes, Boulder, Colorado, June 25-29, 1990, American Meteorological Society, Boston, (1990).

No abstract.

FS-026

MCCOY, M.C. Evaluation of weather forecasts issued with an advanced weather display system: the DAR^{3}E-I workstation. Preprints, 11th Conference on Probability and Statistics, Monterey, California, October 1-5, 1990. American Meteorological Society, Boston, 167-172 (1989).

No abstract.

FS-027

MCCOY, M.C., R.A. Pielke, and P.W. Mielke, Jr. An application of multi-response randomized block permutation procedures (MRBP) to the evaluation of numerical weather prediction models. Preprints, 11th Conference on Probability and Statistics, Monterey, California, October 1-5, 1990. American Meteorological Society, Boston, 192-195 (1989).

No abstract.

FS-028

MCGINLEY, J.A. Diagnosing the preconvective environment using a meso-beta data assimilation system. Proceedings, International Symposium of Assimilation of Observations in Meteorology and Oceanography, Clermont-Ferrand, France, July 9-13, 1990. World Meteorological Organization, 538-543 (1989).

No abstract.

FS-029

MCGINLEY, J.A. Numerical analysis of the influence of jets, fronts, and mountains on lee cyclogenesis: more cases from the ALPEX SOP. Meteorology and Atmospheric Physics, 43, 7-20 (1990).

In a recently published work it was shown that Alpine cyclone development depends on a short wave trough upstream of the Alps, the presence of an upper-level jet streak in this trough, and a low-level front interacting with the mountain barrier. Specifically, by modifying the strength of the upper baroclinic zone (potential vorticity) or by decreasing the strength of the low-level baroclinic zone impinging on the Alps in an initial field, the intensity of the resulting numerically predicted cyclogenesis could be modulated. The major finding of the work was that the ALPEX cyclones reacted different'y to upper-level and lower-level modification, providing a basis for broadly classifying storms: that is, dependence on upper-level processes and on low-level processes. The present work extends this study by considering additional cyclones that occurred during the ALPEX Special Observing Period (SOP), and describes the influence of upper-level and lower-level processes on each. An index (I) discussed in the previous paper is examined in terms of its relative value from case to case, and in terms of its value in a time-dependent sense during the lifetime of the storm. The results show that the most powerful lee cyclones depended more on the strength of the upper-level jet or potential vorticity than on the strength of the low-level front of baroclinic zone. In most cases the time evolution of I showed the influence of the upper-level jet to be important during the early phase of development. The front is increasingly important in midlife as intensification takes place, and the jet is increasingly important during late life. These conclusions were reached during the earlier study but are supported by the additional SOP cyclone cases. Cyclone steering flow and the impinging of the storm on the Alps had a great impact on defining its character: storms with NW-N trajectories were heavily dependent on low level frontal strength and WSW-WNW trajectories were dominated by effects of the upper level jet.

FS-030

MCGINLEY, J.A. The local analysis and prediction system. Preprints, 12th Conference on Weather Analysis and Forecasting, Monterey, California, October 2-6, 1989. American Meteorological Society, Boston, 15-20 (1989).

No abstract.

FS-031

MERREM, F.H. Use of polynomial discrimination functions to forecast 1-hour temperature trends. Preprints, 6th International Conference on Interactive Information and Processing Systems, Anaheim, California, February 5-9, 1990. American Meteorological Society, Boston, 210-216 (1990).

No abstract.

FS-032

MONINGER, W.R. (Ed.). Meeting Report: Third Workshop on Artificial Intelligence Research in Environmental Science (AIRIES). Bulletin, American Meteorological Society, 71, pp. 672-679 (1989).

No abstract.

FS-033

MONINGER, W.R. Shootout-89, an evaluation of Knowledge-based weather forecasting systems. Uncertainty in Artificial Intelligence, M. Henrion, R.D. Shachter, L.N. Kanal, and J.F. Lemmer (editors). Elsevier Science Publishers B.V., North-Holland, pp. 457-458 (1990).

No abstract.

FS-034

MONINGER, W.R., J. Bullas, B. deLorenzis, E. Ellison, J. Flueck, J.C. Mcleod, C. Lusk, P.D. Lampru, R.S. Phillips, W.F. Roberts, R. Shaw, T.R. Stewart, J. Weaver, K.C. Young, and S. M. Zubrick. Shootout-89, A Comparative Evaluation of Knowledge-based Systems that Forecast Severe Weather. Bulletin, American Meteorological Society (1990).

During the summer of 1989, the Forecast Systems Laboratory of the National Oceanic and Atmospheric Administration sponsored an evaluation of artificial-intelligence-based systems that forecast severe convective storms. The evaluation experiment, called Shootout-89, took place in Boulder, Colorado, and focused on storms over the northeastern Colorado foothills and plains. Several systems participated in Shootout-89. These systems included traditional expert systems, an analogue-based system, and a system developed using methods from the cognitive science/judgment analysis tradition. Each day of the exercise the systems generated 2-9 h forecasts of the probabilities of occurrence of nonsignificant weather, significant weather, and severe weather in each of four regions in northeastern Colorado. A verification coordinator working at the Denver Weather Service Forecast Office gathered ground-truth data from a network of observers.

Systems were evaluated on the basis of several measures of forecast skill, and on timeliness, ease of learning, and ease of use. Systems were generally easy to operate, however the various systems required substantially different levels of meteorological expertise on the part of their users -- reflecting the various operational environments for which the systems had been designed. Systems varied in their statistical behavior, but on this difficult forecast problem, the systems generally showed a skill approximately equal to that of persistence forecasts and climatological forecasts.

FS-035

MONINGER, W.R., A. Ignatowski, and R. Fozzard. Progress report on Metalog: A System to capture and maintain environmental metadata. Preprint volume, Sixth International Conference on Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology. American Meteorological Society, Boston. pp. 179-186 (1990).

No abstract.

FS-036

MORAN, K.P., D.B. WUERTZ, R.G. STRAUCH, N.L. ABSHIRE, and D.C. LAW. RASS demonstration on a NOAA network wind profiler. NOAA TM ERL WPL-184, 22 pp. (1990).

The National Oceanic and Atmospheric Administration (NOAA) is constructing a wind profiler network in the central United States to evaluate the utility of nearly continuous wind data and, in particular, its effect on short-term weather forecasting. The UHF (404.37 MHz) radars can also measure vertical profiles of virtual temperature in the lower troposphere by the Radio Acoustic Sounding System (RASS) technique. Vertical temperature data are obtained with the same spatial and temporal resolution that are used for wind profiling. A series of tests was conducted in April and May 1990 to obtain a preliminary evaluation of how well RASS would operate with the new wind profilers for the NOAA network. The network prototype radar, located at Platteville, Colorado, was used to collect RASS data. RASS data from two other profilers were available for comparison. Height coverage of the RASS data began at 500 m above the surface and extended to 3.5-5.2 km with the NOAA network profiler.

FS-037

Pielke, R.A., G. Dalu, J.R. Garratt, T.G.F. Kittel, R.A. Stocker, T.J. Lee, and J.S. Snook. Influence of mesoscale land use on weather and climate and its representation for use in large scale models. Preprints, Indo-U.S. Seminar on The Parameterization of Subgrid-Scale Processes in Dynamical Models of Medium-Range Prediction and Global Climate, Pune, India, 61 pp. (1990).

No abstract.

FS-038

Roberts, W.F., M.R. Bailey, and I.L. Shea. Implementation of SWORD: technology and experience. 6th International Conference on Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology, Anaheim, California, February 5-9, 1990. American Meteorological Society, Boston, 321-328 (1990).

No abstract.

FS-039

Roberts, W.F., W.R. MONINGER, B. deLorenzis, E. Ellison, J. Flueck, J.C. McLeod, C. Lusk, P.D. Lampru, R. Shaw, T.R. Stewart, J. Weaver, K.C. Young, and S. Zubrick. A field test of artificial intelligence systems applied to the problem of severe weather forecasting: Shootout-89. 11th Conference on Probability and Statistics in Atmospheric Sciences, Monterey, California, October 2-6, 1989. American Meteorological Society, Boston, J59-J64 (1989).

No abstract.

FS-040

Roberts, W.F., W.R. MONINGER, B. deLorenzis, E. Ellison, J. Flueck, J.C. Mcleod, C. Lusk, P.D. Lampru, R. Shaw, T.R. Stewart, J. Weaver, K.C. Young, and S. Zubrick. Shootout-89: A Comparative Evaluation of AI systems for Convective Storm Forecasting. Preprint volume, Sixth International Conference on Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology. American Meteorological Society, Boston. pp. 167-172 (1990).

No abstract.

FS-041

SCHULTZ, P. Real-time estimation of cloud microphysical parameters for forecasting applications. Preprints, 12th Conference on Weather Analysis and Forecasting, Monterey, California, October 2-6, 1989. American Meteorological Society, Boston, 481-483 (1989).

No abstract.

FS-042

SCHWARTZ, B.E. Rawinsonde Data: Operational and Archival Concerns. Preprints, 12th Conference on Weather Analysis and Forecasting, Monterey, California, October 2-6, 1989. American Meteorological Society, Boston, 52-57 (1989).

No abstract.

FS-043

SCHWARTZ, B.E. Regarding the Automation of Rawinsonde Observations. Weather and Forecasting 5(1):167-171 (1990).

No abstract.

FS-044

SCHWARTZ, B.E., C.F. Chappell, W.E. Togstad, and X.P. Zhong. The Minneapolis Flash Flood: Meteorological Analysis and Operational Response. Weather and Forecasting 5(1):3-21 (1989).

The evolution of the synoptic- and meso-alpha scale meteorological setting for the July 23, 1987, Minneapolis flash flood is described. Analyses of conventional upper-air data, including quasi-geostrophic processes, are employed to identify the large-scale forcing that set the stage for the development of mesoscale convection. Surface mesoanalysis identified a significant outflow boundary and meso-high-pressure produced from afternoon thunderstorms over east-central Minnesota and western Wisconsin. This outflow boundary became stationary over Minneapolis-St. Paul (the Twin Cities), providing a convergence zone that acted to focus thunderstorm development. Satellite imagery shows that the thunderstorms associated with the mesoscale convective system (MCS) over Wisconsin developed westward during late afternoon and early evening. Radar reflectivity indicated that rapid cell generation occurred just west of the Twin Cities where the outflow boundary from the Wisconsin MCS intersected a second boundary-layer convergence zone oriented east-northeast to west-southwest. A meso-low pressure system exhibiting a line echo wave pattern (LEWP) developed near this intersection or triple point, about 80 km west of Minneapolis. Rapid cell generation occurred just west of the Minneapolis-St. Paul metroplex, and the cells traversed the same area in a "train echo" pattern that produced pulsating heavy rains. Operational response to this multifaceted weather system is also examined. It appears that forecasters were over-burdened with the issuance of both severe thunderstorm and tornado warnings and did not have the time to perform the necessary analyses and diagnoses needed to keep abreast of current weather, and to anticipate future developments. In addition, the overriding concern for hail, high winds, and tornadoes at the expense of overlooking the flash-flood threat may have been partly due to the fact that the operational weather system did not verify flash-flood watches and warnings until 1988. A review of operational procedures suggests that equal emphasis in forecasting severe thunderstorms and forecasting heavy rainfall could improve Weather Service response to future multihazard situations.

FS-045

SMART, J.R. and J.A. MCGINLEY. The use of radar reflectivity to determine snowfall over northeast Colorado. Preprints, 12th Conference on Weather Analysis and Forecasting, Monterey, California, October 2-6, 1989. American Meteorological Society, Boston, 390-395 (1989).

No abstract.

FS-046

Smith, T.L. and S.G. Benjamin. Weather forecasting applications of potential vorticity analyses on isentropic surfaces. Preprints, 12th Conference on Weather Analysis and Forecasting, Monterey, California, October 2-6, 1989. American Meteorological Society, Boston, 260-265 (1989).

No abstract.

FS-047

SNOOK, J.S. Preprints, 12th Conference on Weather Analysis and Forecasting, Monterey, California, October 2-6, 1989. American Meteorological Society, Boston, 500-504 (1989).

No abstract.

FS-048

SNOOK, J.S. and J.A. MCGINLEY. Integration of GOES-VAS sounding data in a local scale analysis. Preprints, 5th Conference on Satellite Meteorology and Oceanography, London, England, September 3-7, 1990. American Meteorological Society, Boston, 349-353 (1990).

No abstract.

FS-049

Stamus, P.A. and J.A. MCGINLEY. Friction on the LAPS high-resolution surface analysis. Preprints, 12th Conference on Weather Analysis and Forecasting, Monterey, California, October 2-6, 1989. American Meteorological Society, Boston, 21-24 (1989). No abstract.

FS-050

Stewart, T.R., W.R. MONINGER, J.A. Flueck, and K. Heideman. Expert Judgment and Weather Forecasting: Does Better Information Lead to Better Forecasts? P.oceedings, 12th Conference on Weather Analysis and Forecasting. pp. J71-2; and Proceedings, 11th Conference on Probability and Statistics in Atmospheric Sciences, p. J71, Monterey, California. American Meteorological Society, Boston (1989).

Extended abstract.

FS-051

Stewart, T.R., W.R. MONINGER, J. Grassia, R.H. Brady, and F.H. MERREM. Analysis of Expert Judgment in a Hail Forecasting Experiment. Weather and Forecasting, 4:24-34 (1989).

This study compared the performance of human forecasters, an expert system, and simple weighted-sum models in a limited-information hail forecasting experiment. It was found that forecasts made by meteorologists were closely approximated by an additive model, and that the model captured most of the skill in the forecasts. Furthermore, the additive model performed as well as the expert system. Initial comparisons suggest that forecasters' skill in this limited-information task did not differ greatly from the skill of forecasts made in field experiments. Results of this study are consistent with the results of extensive psychological research on judgment and decision making processes. Applications of the research to operational weather forecasting are discussed.

FS-052

Szoke, E.J. and J.A. AUGUSTINE. An examination of the mean flow and thermodynamic characteristics of a mesoscale flow feature: the Denver cyclone. 4th Conference on Mesoscale Processes, Boulder, CO, June 25-29, 1990. American Meteorological Society, Boston (1989).

Extended abstracts.

FS-053

TOLLERUD, E.I., J.M. BROWN, and D.L. Bartels. Structure of an MCS-Induced Mesoscale Vortex as Revealed by VHF Profiler, Doppler Radar and Satellite Observations. Preprints, 12th Conference on Weather Analysis and Forecasting, Monterey, California, October 2-6, 1989. American Meteorological Society, Boston, 81-86 (1989).

No abstract.

FS-054

TOLLERUD, E.I., C.G. GRIFFITH, X.P Zhong, and J.A. AUGUSTINE. Changes in Satellite-Derived Precipitation Estimates During the Lifecycles of Mesoscale Convective Systems. Preprints, Conference on Operational Precipitation Estimation and Prediction, Anaheim, California, February 4-9, 1990. American Meteorological Society, Boston, 126-129 (1990).

No abstract.

FS-055

WALKER, D.C. DAR^{3}E-I Evaluation: Forecasters' Assessment and Use of the DAR^{3}E-I System During the 1988 Warm Season. NOAA TR ERL 441-FSL 4, 55 pp. (1990).

This final evaluation of DAR^{3}E-I (Denver AWIPS-90 Risk Reduction and Requirements Evaluation, Part I) is based on forecasters' assessments of the system and their use of workstation products during the 1988 warm season, which extended from May through August. Responses to the third DAR^{3}E-I evaluation questionnaire reveal that forecasters' assessments of the DAR^{3}E-I system are essentially unchanged from those reported earlier (Heideman et al., 1989). They remain enthusiastic about the data sets and products available on the DAR^{3}E-I workstation and about the numerous system capabilities. Similarly, they remain critical of the same aspects of the DAR^{3}E-I system that they previously found unsatisfactory (most of which are being addressed by changes or upgrades planned for the next iteration of the system, DARE-II). Some new information regarding the forecasters' assessments was also gained from this questionnaire. Fewer than one-third of the DAR^{3}E-I application programs received favorable ratings from a majority of the forecasters. Forecasters rated the system high in its utility to help them improve the lead time of severe weather forecasts and predict the occurrence of severe weather. However, they indicated the system was less useful in helping them distinguish severe from near-severe weather (in the context of forecasting/warning). Product usage analysis for the 1988 warm season revealed some interesting changes from previous analyses. Requests for model products increased, especially for MRF (Medium Range Forecast) and NGM (Nested Grid Model) products. Also increased were requests for the MAPS (Mesoscale Analysis and Prediction System) surface products, continuing a trend noted in previous analyses. Substantial use of the new Doppler radar packed Z/V product contributed, paradoxically, to an overall decrease in requests for Doppler radar products. The packed Z/V combines a reflectivity PPI (plan position indicator) and a velocity PPI into a single image, thereby providing forecasters access to two products with only a single request. Finally, a list of the 15 most-requested products continues to be dominated by DAR^{3}E-only and mesoscale products. (DAR^{3}E refers to the whole Denver AWIPS-90 Risk Reduction and Requirements Evaluation, without regard to Part I or Part II.)

FS-056

WALKER, D.C. and K.F. Heideman. DAR^{3}E-I Evaluation: Forecasters' Assessment and Use of the NEXRAD Algorithm Products During the 1987 and 1988 Warm Seasons. NOAA TR ERL 440-FSL 3, 22 pp. (1989).

This evaluation of DAR^{3}E-I (Denver AWIPS-90 Risk Reduction and Requirements Evaluation, Part I) is based on forecasters' experience with the NEXRAD (Next Generation Weather Radar) storm algorithm products (i.e., all nonprecipitation products), as implemented by the Program for Regional Observing and Forecasting Services (PROFS) and available on the DAR^{3}E-I workstation, during the 1987 and 1988 warm seasons, and on their experience with the NEXRAD precipitation algorithm products available during the 1988 warm season. Responses to evaluation questionnaires reveal that some forecasters use the products despite having doubts about their suitability for use in Colorado; others use the products with the belief that they can never have too much information. Overall use of the NEXRAD algorithm products is low; those used most consistently are the precipitation products, despite the fact that some forecasters think the precipitation products may tend to overestimate precipitation amounts. Product usage analysis confirms the overall low use of the NEXRAD algorithm products and the expressed preference of the forecasters for the precipitation products. Forecasters' use of the mesocyclone detection algorithm product and their use of all the storm products presented on the state scale decreased sharply between the 1987 and 1988 warm seasons. Conversely, requests for most of the algorithm products presented on the local scale increased, particularly requests for the VIL/Echo Tops product. The reduced demand for the mesocyclone detection algorithm product may be due to 1) a software coding error, (2) algorithm sensitivity to range-folding errors, or (3) lack of applicability of the algorithm to the type of tornadic storms most common in northeastern Colorado. Reduced demand for algorithm products on the state scale is most likely due to a loss of graphical resolution when products are displayed on this scale. Analysis revealed that the 1988 warm-season storm algorithm products were not being used as integral tools in decisions to issue special weather statements or severe weather warnings. Nonetheless, indications are that the forecasters remain receptive to NEXRAD-type guidance but insist on its being meteorologically reliable and addressing their real-time forecasting needs.

FS-057

WUERTZ, D.B., B.L. WEBER, R.G. STRAUCH, D.A. MERRITT, K.P. MORAN, D.C. LAW, D. VAN DE KAMP, R.B. CHADWICK, M.H. ACKLEY, M.F. BARTH, N.L. ABSHIRE, P.A. MILLER, and T.W. SCHLATTER. Evaluating the performance of the first wind profiler of the new NOAA demonstration network. Proceedings, IGARSS '90, College Park, MD, 20-24 May 1990. IEEE, New York, 533-536 (1990).

No abstract.

FS-058

Zhong, X.P. and E.I. TOLLERUD. Rainfall in Mesoscale Convective Complexes: Spatial Distribution and Seasonal Variation. Preprints, 12th Conference on Weather Analysis and Forecasting, Monterey, California, October 2-6, 1989. American Meteorological Society, Boston, 111-116 (1989).

No abstract.

Addendum

FS-059

MONINGER, W.R., T.R. Stewart, and P. McIntosh. Evaluation of Knowledge-based systems for Probabilistic Forecasting. Proceedings, Validation and Testing of Knowledge-Based Systems Workshop, St. Paul (1988).

Discussion of the issues involved in the evaluation of knowledge-based systems for forecasting weather events, and then discuss how these issues were addressed in three projects. These projects are (1) the development and operational deployment of an expert system to provide guidance about the probability of solar flares, (2) the testing of an expert system that diagnoses hailstorm likelihood, and the generation of a set of judgment models of hail forecasting, and (3) the testing of those models. In this paper, we take a broad view of knowledge-based systems, one that includes rule-based systems, and also includes other models of expert knowledge, such as those based on the methods of judgment analysis.

GEOPHYSICAL FLUID DYNAMICS LABORATORY

GF-001

BRYAN, K. The design of numerical models of the ocean circulation. In Oceanic Circulation Models Combining Data and Dynamics. D.L.T. Anderson and J. Willebrand (eds.). Kluwer Academic Publishers, London, 465-500 (1989).

The design of numerical models is introduced through an analysis of the stability of finite difference approximations of the shallow-water equations. An outline of nonlinear instability, and methods to control it, is followed by a discussion of vertical coordinate systems, and examples of the application of models of various design to the investigation of the large-scale potential vorticity pattern in the main thermocline.

GF-002

BRYAN, K. Climate response to greenhouse warming: The role of the ocean. In Climate and Geo-Sciences, A. Berger, S. Schneider, and J. Cl. Duplessy (eds.). Kluwer Academic Publishers, London, 435-446 (1989).

No abstract.

GF-003

BRYAN, K. A review of "Mathematical modelling of ocean circulation". G.I. Marchuk and A.S. Sarkisyan (eds.). Bulletin of American Meteorological Society 71(2):209-210 (1990).

No abstract.

GF-004

Chang, P., and S.G.H. PHILANDER. Quasi-geostrophic oceanic adjustment in the presence of mean currents. Dynamics of Atmospheres and Oceans 14:387-414 (1990).

The effect of mean currents on the adjustment of the ocean to a change in the winds is studied using a quasigeostrophic shallow water model. In an inviscid ocean the eigenmodes that affect the oceanic adjustment fall into two groups: a finite discrete number of Rossby waves with speeds greater than that of the mean flow, and a continuum of modes that have critical layers where the wave speed equals that of the mean current. In the case of a baroclinic mean current there exists large-scale latitudinal modes that propagate at the speed of long-non-dispersive Rossby waves. Because of their presence, the adjustment in the presence of mean baroclinic currents is very similar to the adjustment in the absence of any currents provided that the forcing has large latitudinal scale. If the continuum of modes with critical layers is important in the adjustment - this is the case if the mean current is barotropic - then the adjustment occurs at approximately the Doppler-shifted Rossby wave speed.

GF-005

COOK, K.H. The atmosphere's response to the ice sheets of the last glacial maximum. Annals of Glaciology 14:32-38 (1990).

This paper discusses some modeling results that indicate how the atmospheric response to the topography of the continental ice of the Last Glacial Maximum (LGM) may be related to the cold North Atlantic Ocean of that time. Broccoli and Manabe (1987) used a three-dimensional general circulation model (GCM) of the atmosphere coupled with a fixed-depth, static ocean mixed-layer model with ice-age boundary conditions to investigate the individual influences of the CLIMAP ice sheets, snow-free land albedos, and reduced atmospheric CO_2 concentrations. They found that the ice sheets are the most influential of the ice-age boundary conditions in modifying the northern hemisphere climate, and that the presence of continental ice sheets alone leads to cooling over the North Alantic Ocean. One approach for extending these GCM results is to consider the stationary waves generated by the ice sheets. Cook and Held (1988) showed that a linearized, steady-state, primitive equation model can give a reasonable simulation of the GCM's stationary waves forced by the Laurentide ice sheet. The linear model analysis suggests that the mechanical effect of the changed slope of the surface, and not changes in the diabatic heating (e.g., the high surface albedos) or time-dependent transports that necessarily accompany the ice sheet in the GCM, is largely responsible for the ice sheet's influence. To obtain the ice-age stationary-wave simulation, the linear model must be linearized about the zonal mean fields from the GCM's ice-age climate. This is the case because the proximity of the cold polar air to the region of adiabatic heating on the downslope of the Laurentide ice sheet is an important factor in determining the stationary waves. During the ice age, cold air can be transported southward to balance this downslope heating by small perturbations in the meridional wind, consistent with linear theory. Since the meridional temperature gradient is more closely related to the surface albedo (ice extent) than to the ice volume, this suggests a

mechanism by which changes in the stationary waves and, therefore, their cooling influence at low levels over the North Alantic Ocean, can occur on time scales faster than those associated with large changes in continental ice volume.

GF-006

COX, M.D. An idealized model of the world ocean. Part I: The global-scale water masses. Journal of Physical Oceanography 19(11):1730-1752 (1989).

A primitive equation, three-dimensional numerical model of the ocean, employing idealized versions of the real topography and surface boundary conditions, is used to study the water mass structure of the World Ocean. In particular, the response of the model to three fundamental changes in boundary conditions is investigated in an attempt to identify the mechanisms in the model which are responsible for the establishment of the largest scale features of the global water-mass structure. With the Drake Passage closed, thermohaline driving alone, and a fresh North Atlantic surface salinity specified, only the coarsest aspects of the observed T and S structure are reproduced and the entire World Ocean below the thermocline is dominated by water formed at the southern boundary. The salinity configuration in particular, lacks much of its observed structure in this case. When the Drake Passage is opened, the resulting circumpolar flow serves to isolate the extreme southern ocean. This allows waters of northern and midlatitude origin to invade the subthermocline zones, producing the familiar tongues of fresh water at intermediate depths. Wind driving further isolates the extreme Southern Ocean and improves the shape and positioning of the fresh water lenses, particularly in the Southern Ocean. Finally, increasing the salinity of water formed at the surface of the Northern Atlantic produces distinct salinity maxima in the deep water throughout the World Ocean, bringing the overall salinity structure into broad agreement with observations. Passive tracers are used to establish water mass origins.

GF-007

DELWORTH, T., and S. MANABE. The influence of soil wetness on near-surface atmospheric variability. Journal of Climate 2(12):1447-1462 (1989).

The influence of land surface processes on near-surface atmospheric variability on seasonal and interannual time scales is studied using output from two integrations of a general circulation model. In the first experiment, of 50 years duration, soil moisture is predicted, thereby taking into consideration interactions between surface moisture budget and the atmosphere. In the second experiment, of 25 years duration, the seasonal cycle of soil moisture is prescribed at each grid point based upon the results of the first integration, thereby suppressing these interactions. The same seasonal cycle of soil moisture is prescribed for each year of the second integration. Differences in atmospheric variability between the two integrations are due to interactions between the surface moisture budget and the atmosphere. Analyses of monthly data indicate that the surface moisture budget interacts with the atmosphere in such a way as to lengthen the time scales of fluctuations of near-surface relative humidity and temperature, as well as to increase the total variability of the atmosphere. During summer months at middle latitudes, the persistence of near-surface relative humidity, as measured by correlations of monthly mean relative humidity between successive months, increases from near zero in the experiment with prescribed soil moisture to as large as 0.6 in the experiment with the interactive soil moisture, which corresponds to an e-folding time of approximately two months. The standard deviation of monthly mean relative humidity during summer is substantially larger in the experiment with interactive soil moisture than in the experiment with prescribed soil moisture. Surface air temperature exhibits similar changes, but of smaller magnitude. Soil wetness influences the atmosphere by altering the partitioning of the outgoing energy flux at the surface into latent and sensible heat components. Fluctuations of soil moisture result in large variations in these fluxes, and thus significant variations in near surface relative humidity and temperature. Because anomalies of monthly mean soil moisture are characterized by seasonal and interannual time scales, they create persistent anomalous fluxes of latent and sensible heat, thereby increasing the persistence of near-surface atmospheric relative humidity and temperature.

GF-008

Derber, J., and A. ROSATI. A global oceanic data assimilation system. Journal of Physical Oceanography 19(9):1333-1347 (1989).

A global oceanic four-dimensional data assimilation system has been developed for use in initializing coupled ocean-atmosphere general circulation models and many other applications. The data assimilation system uses a high resolution global ocean model to extrapolate the information forward in time. The data inserted into the model currently consists only of conventional sea surface temperature observations and vertical temperature profiles. The data are inserted continuously into the model by updating the model's temperature solution every timestep. This update is created using a statistical interpolation routine applied to all data in a 30-day window centered on the present timestep. Large scale features in the sea surface temperature fields created from the assimilation are much more realistic than those produced without the insertion of data. Furthermore, information contained in the assimilation field is shown to be retained in the model solution after the assimilation procedure is terminated. The results are encouraging but further improvements can be made.

GF-009

Derber, J.C. A variational continuous assimilation technique. Monthly Weather Review 117(11):2437-2446 (1989).

A variational assimilation technique is presented which continuously adjusts a model solution by introducing a correction term to the model equations. The technique is essentially a modification of the adjoint technique. The Variational Continuous Assimilation (VCA)

technique optimizes the correction to the model equations rather than the initial conditions as is done in the adjoint technique. The VCA-technique characteristics were examined by inserting independent analyses into a simple quasi-geostrophic model using both the VCA technique and the adjoint technique. Because the model equations do not have to be satisfied exactly in the VCA technique, some of the effects of the systematic model errors can be removed from the assimilation. Thus, the VCA technique was able to consistently fit the data better than the adjoint technique. Predictions from the results from the assimilation techniques showed that the forecast from the adjoint technique's solution was consistently inferior to those from the VCA technique and those from the Geophysical Fluid Dynamics Laboratory's (GFDL's) First GARP (Global Atmospheric Research Program) Global Experiment (FGGE) IIIb analyses. As a by product of the VCA technique, an empirical correction for the model's systematic error is produced. Application of this correction during a forecast produced substantially improved simulations.

GF-010

Feldstein, S.B., and I.M. HELD. Barotropic decay of baroclinic waves in a two-layer beta-plane model. Journal of the Atmospheric Sciences 46(22):3416-3430 (1989).

A two-layer quasi-geostrophic model is used to study the effects of a meridionally sheared zonal flow on the life cycle of a weakly unstable baroclinic wave. In most of the cases analyzed, the fluid is inviscid with the exception of scale-selective fourth-order horizontal diffusion. The initial zonal flow is identically zero in the lower layer. The character of the eddy life cycle in the limit of weak supercriticality is shown to depend on whether or not the meridional shear in the upper layer is strong enough to produce a critical latitude for the wave. If the shear is sufficiently weak, the wave undergoes periodic amplitude vacillation characterized by symmetric baroclinic growth and baroclinic decay. However, when the meridional shear is strong enough to allow for the existence of a critical layer, the flow undergoes an asymmetric life cycle which resembles that found by Simmons and Hoskins in a primitive equation model on the sphere: the wave grows baroclinically but decays barotropically toward a wave-free state. Throughout the barotropic decay stage, the wave is breaking and being absorbed either at or before the critical layer. As the supercriticality is increased, strong reflection begins to occur at the location of the wave breaking, resulting in irregular amplitude vacillation. Consistent with critical layer theory, when a reflecting state is created the solution is sensitive to the inclusion of higher zonal harmonics of the fundamental wave. By relaxing the potential vorticity distribution back to an unstable state, periodic solutions are obtained in which each episode of growth and decay is similar to that found in these nearly inviscid solutions.

GF-011

Fyfe, J., and I.M. HELD. The two-fifths and one-fifth rules for Rossby wave breaking in the WKB limit. Journal of the Atmospheric Sciences 47(6):697-706 (1990).

A stationary Rossby wave, sinusoidal in longitude, is slowly switched on, and the meridional propagation of the resulting wave front through a shear flow is examined. Initially, the flow is westerly everywhere and therefore free of critical layers. The transition from reversible to irreversible behavior as the wave amplitude is increased is described. It is shown that under slowly varying conditions in an inviscid quasi-linear model, a steady state is obtained if, and only if, the mean flow is decelerated by less that two-fifths of its initial value as a result of the passage of the wave front. If this passage causes a larger mean flow reduction, a pile-up of wave activity in the shear layer culminates in the generation of a critical layer, qualitatively as in Dunkerton's model of gravity wave-mean flow interaction. This qualitative picture is shown to be preserved in the quasi-linear model when the slowly varying assumption breaks down. Fully nonlinear calculations show that these quasi-linear results are only part of the story. Once the mean flow is decelerated by two-fifths of its initial value in the fully nonlinear model, rapid wave breaking and irreversible mixing occur in the shear layer. But more slowly developing wave breaking also occurs for wave amplitudes that are too small to produce the two-fifths deceleration. Overturning of contours can be shown to occur in the quasi-linear slowly varying model once the mean flow has been decelerated by one-fifth of its initial value, and this appears to be the critical value for wave breaking to occur in the nonlinear integrations.

GF-012

HAMILTON, K. A look at the recently proposed solar-QBO-weather relationship. Journal of Climate 3(4):497-503 (1990).

Surface meteorological data at several stations over the period 1875-1936 are examined in relation to solar activity. In particular, an attempt is made to see if these historical data can be reconciled with the sun-QBO-weather relationship recently found in modern (post-1950) data by van Loon and Labitzke (vLL). The basic problem in extending vLL's analysis to earlier periods is ignorance of the phase of the QBO. In the present study, vLL's computations are repeated for the historical data using several million possible sequences for the phase of the QBO. The results reveal problems in reproducing vLL's results in the earlier data. This indicates either that the QBO behaved differently in the past, or that vLL's results for a solar-weather relationship are not stable over the long term.

GF-013

HELD, I.M., and M. Ting. Orographic versus thermal forcing of stationary waves: The importance of the mean low-level wind. Journal of the Atmospheric Sciences 47(4):495-500 (1990).

The amplitude of the linear, stationary response to low-level extratropical heating decreases as the magnitude of the low-level mean flow increases, while the amplitude of the orographically forced waves increases. As a result, linear theory predicts that the relative importance of thermal and orographic forcing for the extratropical stationary wave field is very sensitive to the magnitude of the zonal mean low-level winds. In the process of illustrating this sensitivity, we also show how the dependence of the orographic response on the low level winds can be distorted by a numerical σ-coordinate model.

GF-014

HELD, I.M., and P.J. PHILLIPPS. A barotropic model of the interaction between the Hadley cell and a Rossby wave. Journal of the Atmospheric Sciences 47(7):856-869 (1990).

A barotropic model is described that is designed to study the interaction of the Hadley Cell with a Rossby wave forced in midlatitudes by a stationary "topographic" source. The Hadley cell is driven by a mass source/sink that is partly fixed, representing solar heating, and partly dependent on the layer thickness, representing infrared cooling. The response of the mean zonal and meridional winds to infinitesimal wave forcing is analyzed in detail; then the forcing is gradually increased to examine the departures from linearity.

GF-015

Karoly, D.J., R.A. Plumb, and M. Ting. Examples of the horizontal propagation of quasi-stationary waves. Journal of the Atmospheric Sciences 46(18):2802-2811 (1989).

Examples of the diagnostics of the horizontal propagation of stationary wave activity proposed by Plumb are presented for a simple model of the atmospheric response to thermal forcing in the tropics, for the observed Southern Hemisphere winter mean stationary waves and for several cases of anomalous quasi-stationary waves in both the northern and southern hemispheres. For the simple model, the propagation of wave activity out of the tropics is clear. From the observational data, the apparent sources of anomalous stationary wave activity are located in the regions of the major middle latitude jets and storm tracks in both hemispheres, in most cases. The results suggest that midlatitude process, such as instabilities of the jet stream or interaction with transient eddies, are the major mechanisms for forcing anomalous stationary waves. There are indications that Rossby-like wave propagation from low latitudes plays a role in forcing anomalous stationary waves associated with southern oscillation events and with some cases of anomalous stationary waves in the Southern Hemisphere.

GF-016

Karoly, D.J. The role of transient eddies in low-frequency zonal variations of the Southern Hemisphere circulation. Tellus 42A:41-50 (1990).

The dominant modes of low-frequency variation of the Southern Hemisphere (SH) circulation in winter have been identified using 15 years of monthly mean analyses of the SH troposphere. The two leading modes are primarily zonally-symmetric, representing out-of-phase variations of geopotential height between middle and high latitudes in one case and between the tropics and middle latitudes in the other. There are accompanying variations of zonal wind and structure in the extratropics. The two modes represent 25% of the variance of the monthly mean height in the SH. The high-latitude mode is also the dominant pattern of variation of 5-day average height anomalies, indicating that this is an important mode on time scales from about a week to a season. Using composites of monthly mean fields and transient eddy statistics for opposite extremes of this high latitude mode, the interaction between transient eddies and the anomalous mean flow is described. During one extreme of the variation, there is an increased height gradient, a stronger zonal jet and more baroclinicity at high latitudes. Although there may be some doubt about the reliability of the transient eddy statistics, they show an enhanced storm track at high latitudes, with transient eddy fluxes which help to maintain the anomalous mean flow.

GF-017

KURIHARA, Y., M.A. BENDER, and C.L. Kerr. An improved numerical scheme to treat the open lateral boundary of a regional model. Monthly Weather Review 117(12):2714-2722 (1989).

A numerical scheme proposed by Kurihara and Bender is modified so as to improve the behavior of open lateral boundaries of a regional model. In the new scheme, both the local values and the gradients of fields from a larger model are used to define the time-dependent reference values toward which the boundary gridpoint values of the regional model prediction are relaxed at each step of the model integration. Use of the gradients in the boundary forcing imposes constraints on the vorticity, divergence and baroclinicity fields for the regional model. The relaxation time of forcing is set to be short for the normal component of wind. For other variables, the relaxation time at a given boundary gridpoint depends on the wind direction at that gridpoint, with a minimum at a point of normal inflow and a maximum at a point of normal outflow. The forcing strength is reduced in the planetary boundary layer so that the boundary layer structure is determined mainly by the surface condition of the regional model. Also, a simple method to control the total mass in the regional model is described. Numerical results from 96-hour integrations with the improved scheme are compared with those from the previous scheme for the cases of the propagations of a wave and a vortex. The behavior of the model at the lateral boundary was noticeably improved with the use of a new scheme, while the solution in the interor domain was little affected by the scheme modifications.

GF-018

LEVITUS, S. Interpentadal variability of temperature and salinity in the deep North Atlantic, 1970-1974 versus 1955-1959. Journal of Geophysical Research 94(C11):16,125-16,132 (1989).

Historical hydrographic observations have been composited and objectively analyzed for the North Atlantic Ocean for two pentads, 1955-59 and 1970-74, for the purpose of studying the temporal variability of the thermohaline structure of the deep North Atlantic Ocean. Statistically significant differences between the two pentads are found in the deep ocean. At 1750 m depth most of the North Atlantic increased in temperature (approximately 0.1°C) and salinity (0.025‰) from the earlier to the later period. An exception to this was a region in the eastern Atlantic between 33°N and 50°N where a cooling (0.1°C) and freshening (0.025‰) occurred. Changes at other depths as evidenced by difference fields of temperature along 25.5°N and 36.5°N are in agreement with differences found by Roemmich and Wunsch (1984) who described changes at these latitudes between sections taken in the late 1950's and sections taken in 1981.

GF-019

LEVITUS, S. Interpentadal variability of steric sea level and geopotential thickness of the North Atlantic Ocean, 1970-1974 versus 1955-1959. Journal of Geophysical Research 95(C4):5233-5238 (1990).

We have composited and objectively analyzed historical hydrographic observations for the North Atlantic Ocean for two periods, 1955-1959 and 1970-1974. Difference fields of steric sea level and geopotential thickness for the North Atlantic Ocean in the 0- to 1500-m depth range between the portion of the subtropical gyre, steric sea level decreased by up to 17.5 dyn cm whereas in the western subarctic gyre (north of the Gulf Stream) steric sea level increased by an amount up to 7.5 dyn cm from the earlier to the later pentad. A decrease in steric sea level (-5 dyn cm) occurred along the eastern boundary of the North Atlantic.

GF-020

LIPPS, F. On the anelastic approximation for deep convection. Journal of the Atmospheric Sciences 47(14):1794-1798 (1990).

A brief review of the scale analysis of Lipps and Hemler is given without any reference to the parameters G and B. The resulting anelastic equations conserve energy, in contrast to the modified anelastic set of equations analyzed by Durran. In addition, the present equations give an accurate solution for the frequency of gravity waves in an isothermal atmosphere. The present anelastic equations have these characteristics in common with the pseudo-incompressible equations introduced by Durran. The equations obtained from the scale analysis are appropriate for numerical integration of deep convection. The associated Poisson equation can be solved using standard procedures. For the pseudo-incompressible set of equations, the Poisson equation is more difficult to solve.

GF-021

MANABE, S., and A.J. BROCCOLI. Mountains and arid climates of middle latitudes. Science 247:192-195 (1990).

Simulations from a global climate model with and without orography have been used to investigate the role of mountains in maintaining extensive arid climates in middle latitudes of the Northern Hemisphere. Dry climates similar to those observed were simulated over central Asia and western interior North America in the experiment with mountains, whereas relatively moist climates were simulated in these areas in the absence of orography. The experiments suggest that these interior regions are dry because general subsidence and relatively infrequent storm development occur upstream of orographically induced stationary wave troughs. Downstream of these troughs, precipitation, bearing storms develop frequently in association with strong jet streams. In contrast, both atmospheric circulation and precipitation were more zonally symmetric in the experiment without mountains. In addition, orography reduces the moisture transport into the continental interiors from nearby oceanic sources. The relative soil wetness of these regions in the experiment without mountains is consistent with paleoclimatic evidence of less aridity during the late Tertiary, before substantial uplift of the Rocky Mountains and Tibetan Plateau is believed to have occurred.

GF-022

MANABE, S., and T. DELWORTH. The temporal variability of soil wetness and its impact on climate. Climatic Change (16):185-192 (1990).

The temporal variability of soil wetness and its interactions with the atmosphere were studied using a general circulation model of the atmosphere. It was found that time series of soil wetness computed by the model contain substantial amounts of variance at low frequencies. Long-time-scale anomalies of soil moisture resemble the red noise response of the soil layer to white noise rainfall forcing. The dependence of the temporal variability of soil moisture on potential evaporation and precipitation is discussed.

GF-023

MANABE, S., K. BRYAN, and M.J. SPELMAN. Transient response of a global ocean-atmosphere model to a doubling of atmospheric carbon dioxide. Journal of Physical Oceanography 20(5):722-749 (1990).

The transient response of climate to an instantaneous increase in the atmospheric concentration of carbon dioxide has been investigated by a general circulation model of the coupled ocean-atmosphere-land system with global geography and annual mean insolation. An equilibrium climate of the coupled model is perturbed by an abrupt doubling of the atmospheric carbon dioxide. The evolution of the model climate during the 60-year period after the doubling is compared with the result from a control integration of the model without the doubling. The increase of surface air temperature in middle and high latitudes is slower in the Southern Hemisphere than the Northern Hemisphere. The large thermal inertia of the ocean-dominated hemisphere is partly responsible for this difference. The effective thermal inertia of the oceans becomes particularly large in high southern latitudes. Owing to the absence of meridional barriers at the latitudes of the Drake Passage, a wind-driven deep cell of meridional circulation is maintained in the Circumpolar Ocean of the model. In addition, a deep reverse cell develops in the immediate vicinity of the Antarctic Continent. The thermal advection by these cells and associated convective overturning result in a very efficient mixing of heat in the 2-km thick upper layer and increase the effective thermal inertia of the ocean, thereby contributing to the slow down of the CO_2-induced warming of the near-surface layer of the Circumpolar Ocean of the model. It is surprising that, during the last 15 years of the 60-year experiment, sea surface temperatures in the Circumpolar Ocean actually reduce with time. Because of the increase in precipitation caused by the enhanced penetration of warm, moisture-rich air aloft into high latitudes, the surface halocline of the Circumpolar Ocean intensifies, thereby suppressing the convective mixing between the surface layer and the warmer underlying water. Thus, sea surface temperature is reduced in the Circumpolar Ocean towards the end of the experiment. In the Northern Hemisphere, the CO_2-induced warming of the lower troposphere increases with increasing latitudes and is at a maximum near the North Pole due partly to the albedo feedback process involving sea ice and snow cover. The warming of the upper ocean layer also increases with increasing latitudes up to about 65°N where the absorption of solar radiation increases markedly due to the poleward retreat of sea ice. Over the Arctic Ocean, the warming is very large in the surface layer of the model atmosphere, whereas it is very small in the underlying water. Both sea ice and a stable surface halocline act as thermal insulators and are responsible for the large air-sea contrast of the warming in this region. In short, the CO_2-induced warming of the sea surface has a large interhemispheric asymmetry, in qualitative agreement with the results from a previous study conducted by use of a coupled model with a sector computational domain and an idealized geography. This asymmetry induces an atmospheric response which is quite different between the two hemispheres.

GF-024

MIYAKODA, K., and J. SIRUTIS. Subgrid-scale physics in 1-month forecasts. Part II: Systematic error and blocking forecasts. Monthly Weather Review 118(5):1065-1081 (1990).

The capability of blocking prediction is investigated with respect to four models of different subgrid scale parameterization packages, which were described in Part I. In order to assess the capability, blocking indices are defined, and threat and bias scores are set up for the predicted blocking index against the observation. Applying this evaluation scheme to the dataset of one-month forecasts for eight January cases we conducted a study on the performance of blocking simulation. First, it is immediately disclosed that the systematic biases in this forecast set are overwhelmingly large, so that the blocking index has to be adjusted to this bias. One of the major issues, suggested by Tibaldi and Molteni, is whether the systematic bias is generated by the failure of blocking forecasts. Overall, this study supports this assertion, despite the different definitions of blocking. The study also reveals that the A-model is inferior to the other three models, such as the E-model, with regard to blocking forecasts. The reason for this is that the E-model, for example, which includes turbulence closure parameterization, appears to provide an adequate conversion of low-frequency eddy potential to kinetic energy, and thereby produces a more reasonable amount of standing eddies related to the persistent ridges. It is also pointed out that the blocking activity in the winter northern hemisphere is manifested by a distinct subpolar peak in the meridional distribution of standing eddy kinetic energy. The E-model tends to generate a well-defined peak of this energy distribution. All models are deficient in expanding the zonal mean westerlies to higher latitudes, particularly the A-model. In this connection, a hypothesis is postulated on a precondition for blocking: the upstream westerlies prior to the onset have to be displaced relatively at lower latitude. In the successful cases of blocking forecasts, the upstream westerlies at 40°-60°N are relatively weaker than those in the unsuccessful cases.

GF-025

MOXIM, W.J. Simulated transport of NO_y to Hawaii during August: A synoptic study. Journal of Geophysical Research 95(D5):5717-5729 (1990).

Using data sets generated by the Geophysical Fluid Dynamics Laboratory general circulation/transport model's U.S.-Canada combustion nitrogen source experiment, a detailed analysis of the simulated transport mechanisms producing the observed August NO_y maximum at Hawaii is presented. Combustion nitrogen is not simply advected from the United States to Hawaii by the winds circulating around the climatological subtropical anticyclone. Rather, its transport results from a complicated three-way interaction of surface advection from source regions, enhanced vertical diffusion due to dry convection, and winds in the "free troposphere." Backward trajectories from Hawaii using model pressure and isentropic surfaces were insufficient in explaining the transport. Model-consistent three-dimensional trajectories revealed that the transport originated in the "free troposphere" along a path from northern Baja to the Texas Gulf coast. Combustion nitrogen from the source regions of southern California and as distant as the Texas Gulf area is advected along the surface toward the arid areas of Baja, the desert southwest, northern Mexico, and west Texas. Dry convection then vertically mixes the air to pressures of 800-650 mbar, where the subsiding wind flow from the east-northeast transports the No_y to Hawaii. Observed wind fields and heights of dry convection are compared to the model where data are available.

GF-026

Nakamura, N., and I.M. HELD. Nonlinear equilibration of two-dimensional Eady waves. Journal of the Atmospheric Sciences 46(19):3055-3064 (1989).

The initial-value problem for Eady's model is re-examined using a two-dimensional (x-z) primitive equation model. It is generally accepted that a finite amplitude instability of Eady's basic state will produce a frontal discontinuity in a finite time. When diffusion prevents the frontal discontinuity from forming, the wave amplitude eventually stops growing and begins to oscillate. We analyze this equilibration and suggest that it is a result of enhanced potential vorticity in the frontal region that is mixed into the interior from the boundaries. The dynamics of equilibration is crudely captured in a modified quasi-geostrophic model in which the zonal-mean static stability is allowed to vary. The magnitude of the meridional wind speed of the equilibrated wave is $O(N_0H)$, where N_0 is the initial buoyancy frequency and H is the depth of the fluid. This is of the same order as the amplitude of the wave predicted by semigeostrophic theory at the point of frontal collapse. Scaling arguments are presented to determine the three-dimensional flows for which the equilibration mechanism should be important. It is argued that this mechanism is likely to be of some importance for shallow cyclones forming in regions of weak low-level static stability.

GF-027

OORT, A.H. Angular momentum cycle in the atmosphere-ocean-solid earth system. Bulletin of the American Meteorological Society 70(10):1231-1242 (1989).

Some of the contributions of Victor Paul Starr (1906-76) as a scholar and teacher at the Massachusetts Institute of Technology are described. His work on the atmospheric branch of the earth's angular momentum cycle is emphasized. Certain recent efforts to include the oceanic and solid earth branches of the cycle are discussed.

GF-028

PHILANDER, G. El Niño and La Niña. American Scientist (77):451-459 (1989).

No abstract.

GF-029

PHILANDER, S.G.H., N.-C. LAU, M.J. NATH, and R.C. PACANOWSKI. Two different simulations of the Southern Oscillation and El Niño with coupled ocean-atmosphere general circulation models. Philosophical Transactions of the Royal Society London A 329:167-178 (1989).

Two different coupled ocean-atmosphere models simulate irregular interannual fluctuations that in many respects resemble El Niño and cold La Niña phases of the oscillation are realistic. This success indicates that the models capture certain aspects of the interactions between the ocean and atmosphere that cause the Southern Oscillation. The principal difference between the models, namely the prominence of oceanic Kelvin waves in one but not the other, causes the two models to differ significantly in the way El Niño episodes evolve, and in the mechanisms that cause a turnabout from El Niño to La Niña and vice versa. It is possible that the different processes that determine the properties of the simulated oscillations all play a role in reality, at different times and in different regions. Each of the models captures some aspects of what is possible. However, reality is far more complex than any model developed thus far and additional processes not yet included are also likely to have a significant influence on the observed Southern Oscillation.

GF-030

Sheng, J., and Y. HAYASHI. Observed and simulated energy cycles in the frequency domain. Journal of the Atmospheric Sciences 47(10):1243-1254 (1990).

The analysis of spectral energetics in the frequency domain has been applied to several observed datasets and those simulated by a GFDL general circulation model. There exists a good agreement on the directions of energy flows between the observed and the simulated atmospheres. The conversion from available potential energy to kinetic energy in the tropics and extratropics is the major source of eddy kinetic energy for all the low and high frequency bands discussed. The energy balance in the tropics has quite different characteristics from those in the extratropics. Instead of an upscale decascade as in the case of the extratropics, kinetic energy is transferred in an opposite sense, namely from transients of longer time scales to those of shorter time scales. Using a 5-year data set from the ECMWF operational analysis, an energy cycle is obtained that is in general agreement with the one computed using the data of the FGGE year alone. The interannual variability of the spectral estimates is relatively small compared with the discrepancies caused by the variety of data origins.

GF-031

Sheng, J., and Y. HAYASHI. Estimation of atmospheric energetics in the frequency domain during the FGGE year. Journal of the Atmospheric Sciences 47(10):1255-1268 (1990).

The energetics of atmospheric motions are studied in the frequency domain using the two versions of the FGGE IIIb dataset, processed at GFDL and ECMWF. It is demonstrated that the frequency spectra of kinetic energy (KE) and available potential energy (APE) can be approximated by a power law. On a log-log diagram, a slope of minus one results for both KE and APE in the period range of 7 to 35 days, when integrated over the Northern Hemisphere. The conversion from APE to KE is the major source of eddy kinetic energy for all the low and high frequency bands discussed. Through nonlinear interactions, motions of high frequencies (with periods shorter than 10 days) gain APE from, and lose KE to the motions of low frequencies (with periods longer than 10 days but shorter than the annual cycle). The nonlinear energy exchanges are relatively more important for the energy balance of low frequency modes. It is also shown that both high and low frequency transients extract APE from and supply KE to the time-mean flow. The intercomparisons between the two versions of FGGE data indicate an overall agreement between the energy cycles derived from the GFDL and ECMWF datasets, despite the differences in calculated values of spectral estimates.

GF-032

SIRUTIS, J., and K. MIYAKODA. Subgrid-scale physics in 1-month forecasts. Part I: Experiment with four parameterization packages. Monthly Weather Review 118(5):1043-1064 (1990).

Four packages of subgrid-scale (SGS) physics parameterization are tested by including them in a general circulation model and by applying the four models to 1-month forecasts. The four models are formulated by accumulatively increasing the elaboration and the sophistication of the physics. The first is the reference model (the A-physics); the second model (the E-physics) uses the Monin-Obukhov similarity theory for the fluxes of surface boundary layer, the turbulence closure scheme for the fluxes in the entire atmosphere, and subsurface soil heat conduction; the third model (the F-physics) replaces the cumulus parameterization by the Arakawa-Schubert method; and the fourth model (the FM-physics) enhances the SGS orography. One-month integrations are performed for eight January cases, with each case consisting of three different forecasts. Originally, the forecast performance was expected to be a stepwise improvement with the elaboration of the SGS physics from the A to the FM, but the forecast results do not show up in such a simple way. The impact of these processes on the 1-month integration is subtle and yet significant. The superiority of the F-model over the A- and the E-models is evident in the last 10 days of the 1-month forecasts, though the performance of the E-model is consistently good, in comparison with the other models, in terms of root-mean-square (rms) error of geopotential height. It is likely that 80% condensation criterion in the E (instead of 100%) is at least partly responsible for the forecast deterioration in the last 10 days, compared with the F. The FM-model gives the lowest rms error, but the predicted transient eddies are extremely low, probably due to the excessively enhanced orography. The simulated global precipitation patterns are presented for the different models, and the drawbacks are discussed. The F- and the FM-models produce spatially smooth distribution of tropical rainfall. The 30-day forecast performance appears to be more sensitive to the initial conditions, rather than the SGS physics. The systematic errors in all of the models are substantial in magnitude, though they vary with the SGS physics.

GF-033

STOUFFER, R.J., K. BRYAN, and S. MANABE. Interhemispheric asymmetry in climate response to a gradual increase of atmospheric CO_2. Nature 342(6250):660-662 (1989).

The transient response of a coupled ocean-atmosphere model to an increase of atmospheric carbon dioxide has been the subject of several studies. The models used in these studies explicitly incorporate the effect of heat transport by ocean currents and are different from the model used by Hansen et al. Here we evaluate the climatic influence of increasing atmospheric carbon dioxide using a coupled model recently developed at the NOAA Geophysical Fluid Dynamics Laboratory. The model response exhibits a marked and unexpected interhemispheric asymmetry. In the circumpolar ocean of the Southern Hemisphere, a region of deep vertical mixing, the increase of surface air temperature is very slow. In the Northern Hemisphere of the model, the warming of surface air is faster and increases with latitude, with the exception of the northern North Atlantic, where it is relatively slow because of the weakening of the thermohaline circulation.

GF-034

Thiele, G., and J.L. Sarmiento. Tracer dating and ocean ventilation. Journal of Geophysical Research 95(C6):9377-9391 (1990).

The interpretation of transient tracer observations depends on difficult to obtain information on the evolution in time of the tracer boundary conditions and interior distributions. Recent studies have attempted to circumvent this problem by making use of a derived quantity, age, based on the simultaneous distribution of two complementary tracers, such as tritium and its daughter, helium 3. The age is defined with reference to the surface such that the boundary condition takes on a constant value of zero. We use a two-dimensional model to explore the circumstances under which such a combination of conservation equations for two complementary tracers can lead to a cancellation of the time derivative terms. An interesting aspect of this approach is that mixing can serve as a source or sink of tracer based age. We define an idealized "ventilation age tracer" that is conservative with respect to mixing, and we explore how its behavior compares with that of the tracer-based ages over a range of advective and diffusive parameters.

GF-035

Zhu, X. Carbon dioxide 15 μm band cooling rates in the upper middle atmosphere calculated by Curtis Matrix Interpolation. Journal of the Atmospheric Sciences 47(6):755-774 (1990).

A new algorithm for calculating CO_2 15 μm band cooling rate is suggested following a similar idea proposed by Fels and Schwarzkopf in 1981. Since the Curtis Matrix is more useful in cooling rate calculations, we show in this paper that it is possible to calculate the Curtis Matrix by direct interpolation with precomputed Curtis Matrices. The algorithm is applied to the calculation of the CO_2 15 μm band cooling rate in the upper-middle atmosphere (64-106 km). The stored Curtis Matrices are off-line computed by escape functions with an appropriate treatment of the nearby layer calculations. These escape functions are calculated by line-by-line integrations. With precomputed Curtis Matrices an accurate atmospheric cooling rate by CO_2 can be calculated more objectively than with transmission functions. A multi-energy-level model to treat the non-LTE problem in this region is also derived systematically. It is shown that when vibration-vibration (V-V) transitions are neglected cooling rate calculations of the multi-energy-level model could be approximated by the usual two-energy-level model with the revised ratio of relaxation rates. Since the complete solution of the non-LTE problem including V-V transitions requires tremendous amounts of computation time due to nonlinearity, it is suggested that such a two-energy-level model can be used in GCM's to approximate the total cooling rate by the whole band.

GREAT LAKES ENVIRONMENTAL RESEARCH LABORATORY

GL-001

Bedford, K.W., C.J. Merry, and D.J. SCHWAB. Real-time Lake Erie current and temperature field forecasting - An integrated modeling and AVHRR methodology. Proceedings, 1989 American Society of Photogrammetry and Remote Sensing and the American Congress on Surveying and Mapping Fall Convention, Cleveland, OH, September 17-21, 1989, 77-78 (1989).

This presentation is offered in the nature of a concept review. A real-time forecasting system is being developed to predict the three-dimensional distributions of currents and temperature in each of the Great Lakes. Two-dimensional surface distributions of water-level, wind waves, and shoreline erosion potential are to be predicted as well. The Lake Erie Forecasting System (LEIFS) is the first of the Great Lakes to be implemented. Temperature calculations proceed with knowledge about the existing temperature state of the Lake and the surface heat transfer rate. AVHRR satellite data and a network of privately and publicly held temperature data are being used to provide these data. This presentation reviews elements of the proposed forecasting concept and its thermal data component.

GL-002

Bedford, K.W., and D.J. SCHWAB. Preparation of real-time Great Lakes forecasts. Cray Channels Summer 1990:14-17 (1990).

No abstract.

GL-003

Bedford, K.W., C.-C. Yen, J. Kempf, D.J. SCHWAB, R. Marshall, and C. Kuan. A 3D-stereo graphics interface for operational Great Lakes forecasts. Proceedings, Estuarine and Coastal Modeling Conference, Newport, RI, November 15-17, 1989. American Society of Civil Engineers, 248-257 (1990).

A system for real-time predictions of Great Lakes physics and transport characteristics is now being implemented. The full 3D nature of the predictions demands accurate, high speed computer visualized representations of the results and therefore this article presents the user interface for this system which fully integrates a graphics philosophy at every level of the forecasting system. Steering, tracking, and pre- and post processing are possible and the full use of 3D stereo animations is being exploited to the extent of its utility.

GL-004

BEETON, A.M. A vision of the future. Proceedings, The Great Lakes Basin: A Regional Focus on the Environment and Human Health, Chicago, IL, October 16-18, 1988. Great Lakes Coalition of Public Health Associations, 31-35 (1989).

No abstract.

GL-005

CARRICK, H.J., and G.L. FAHNENSTIEL. Biomass, size structure, and composition of phototrophic and heterotrophic nanoflagellate communities in Lakes Huron and Michigan. Canadian Journal of Fisheries and Aquatic Sciences 46(11):1922-1928 (1989).

The abundance and biomass of surface (5 m) and deep (20-45 m) nanoflagellate communities in Lakes Huron and Michigan were determined during 1987. Abundances (10^3-10^5 cells$\cdot$mL^{-1}) were comparable between lakes and similar to those reported from other oligotrophic environments. Community composition was skewed towards the small end of the size spectrum due to the prevalence of small chrysomonads. In general, heterotrophic flagellates (Hnano) were more abundant than phototrophic flagellates (Pnano), while standing stocks of Pnano carbon (average 24.7 μg C$\cdot$L^{-1}) were greater than Hnano carbon (9.6 μg C$\cdot$L^{-1}) on nearly all sample dates. The abundance of nanoflagellates in both Lakes Huron and Michigan peaked in July, perhaps indicating increased growth at higher temperatures and/or a response to higher abundance of prey. Nanoflagellate communities in deep waters during thermal stratification were more abundant (50-70% higher carbon) than surface communities and were dominated by Pnano. High carbon standing stocks of deep communities did not correspond with high prey abundances. Thus, deep communities seem to be influenced by factors (e.g., light and nutrients) that maintain deep phytoplankton communities in the upper Great Lakes. While Hnano are quantitatively important in Lakes Huron and Michigan, representing nearly 20% of phytoplankton biomass, their trophic role is largely unknown.

GL-006

CARRICK, H.J., and G.L. FAHNENSTIEL. Planktonic protozoa in Lakes Huron and Michigan: seasonal abundance and composition of ciliates and dinoflagellates. Journal of Great Lakes Research 16(2):319-329 (1990).

The abundance and biomass of surface (5 m) and deep (30-45 m) ciliate and dinoflagellate protozoa in the offshore waters of Lakes Huron

and biomass (13-140 mg•L^{-1}, wet wt.) were comparable between lakes and similar to those reported from other oligotrophic environments. On average, ciliates comprised the majority of protozoan abundance (80%) and biomass (73%). The mean size (ESD) of these communities was small (20.6 mm) due to the numerical dominance of small choreotrichs, oligotrichs, and species of Gymnodinium. Total biomass in both lakes peaked during late June-July and again during the October-November period. These seasonal changes in biomass were accompanied by species replacements: tintinnids, strobilids, oligotrichs, and Gymnodinium species were abundant in the spring isothermal period, shifting to oligotrich dominance during summer stratification (May-July); a more diverse assemblage followed during late stratification (October-November) in which haptorids, prorodontids, and Peridinium species became more important. Deep and surface communities were comparable in terms of abundance and biomass, although deep community biomass decreased as stratification intensified. Because the biomass of ciliates alone represents approximately 30% of crustacean zooplankton biomass, protozoa may be more important grazers than once thought.

GL-007

Chin, Y.-P., W.J. Weber, Jr., and B.J. EADIE. Estimating the effects of dispersed organic polymers on the sorption of contaminants by natural solids. 2. Sorption in the presence of humic and other natural macromolecules. Environmental Science and Technology 24(6):837-842 (1990).

A triphase distribution model was used in conjunction with experimental observations to characterize the effects of humic polymers dispersed in an aqueous phase on the sorption of hydrophobic organic compounds from that phase by natural solids. The organic compound-humic substance binding constants employed in the model were estimated using a partition equation that takes into account the solubility of the solute in both the aqueous and organic polymer phases as developed in the first paper of this two part series. Experimental results and model predictions indicate that the sorption of moderately hydrophobic compounds by lacustrine sediments is relatively unaffected by the presence of humic polymers, but that the sorption of highly insoluble organic contaminants by the same sorbents is sensitive to small amounts of background organic polymers. The observations support earlier analyses by other investigators regarding the impact of the organic subphases on the fate and transport of pollutants in natural aquatic systems.

GL-008

CROLEY, T.E., II. Great Lakes hydrological impacts of $2xCO_2$ climate change. Proceedings, International and Transboundary Water Resources Issues, Toronto, Ontario, Canada, April 1-5, 1990. American Water Resources Association, 595-604 (1990).

The Great Lakes Environmental Research Laboratory considered climate change impacts on North American Great Lakes hydrology by using recent atmospheric general circulation model (GCM) simulations of a doubling of atmospheric CO_2, available from the Goddard Institute for Space Studies. We made changes in historical meteorological data, similar to the changes observed in the GCM, and observed the impact of the changed data in hydrology models for basin moisture storage and runoff, over-lake precipitation, and lake heat storage and evaporation. While precipitation changes are uncertain, higher air temperatures generally increase basin evapotranspiration which decreases the snowpack, lowers runoff, shifts runoff peaks, and reduces soil moisture. There are larger amounts of heat resident in the deep lakes reducing buoyancy-driven turnovers of the water column, lowering ice formation, and increasing lake evaporation.

GL-009

EADIE, B.J., N.R. MOREHEAD, and P.F. LANDRUM. Three-phase partitioning of hydrophobic organic compounds in Great Lakes waters. Chemosphere 20(1-2):161-178 (1990).

Great Lakes waters were freshly collected, innoculated with radiolabelled hydrophobic organic compounds and, after equilibration, separated into particle bound, dissolved organic matter bound and freely dissolved phases. In these ambient suspended matter (0.2-5 ppm) and dissolved organic carbon (1-6 ppm) media, the freely dissolved phase generally dominates and the amounts associated with dissolved organic matter rarely exceeds 5% for most compounds. Solubility controls the constituent distribution between particle bound and freely dissolved but plays a much smaller role in mediating the binding to dissolved organic matter. Differences observed in the binding to dissolved and particulate organic matter support the need to consider the distribution of constituents among three phases. Although the concentration and composition of the substrate changes significantly, there is no apparent seasonal effect on the distribution of compounds among the three phases in the Great Lakes.

GL-010

EADIE, B.J., H.A. VANDERPLOEG, J.A. ROBBINS, and G.L. BELL. Significance of sediment resuspension and particle settling. In Large Lakes: Ecological Structure and Function, M.M. Tilzer and C. Serruya (eds.). Springer-Verlag, New York, 196-209 (1990).

Seasonal particle characteristics and sediment-trap-measured resuspension rates are examined for the Laurentian Great Lakes and compared with other large, deep lakes. Results are used to estimate the influence of particle-related processes on the current chemical composition of these lakes. Even in deep systems such as the Laurentian Great Lakes, particle settling times are relatively short and compounds with a high affinity for particulate matter are efficiently scavenged and removed to the sediments. After reaching the bottom, the settled materials are mixed by the feeding activities of bottom-dwelling organisms into an homogenized pool representing years-to-decades of recent sedimentation. It is apparent from the relatively slow decline of the concentrations of these particle-associated constituents in water and biota that sediments are a leaky sink; small concentrations persist for decades because of processes that can remobilize materials from the bottom.

GL-011

Edgington, D.N., and J.A. ROBBINS. Time scales of sediment focusing in large lakes as revealed by measurement of fallout Cs-137. In Large Lakes: Ecological Structure and Function, M.M. Tilzer and C. Serruya (eds.). Springer-Verlag, New York, 210-223 (1990).

The sediments of large lakes provide a sink for many of the trace contaminants that have been mobilized in the environment. Several models have been developed to describe the resultant concentration profiles in sediment cores - in terms of input fluxes, sedimentation rates, and mixing depths. Implicit in these models are the assumption that sedimenting particles are disconnected from prior input events and that transport is only by vertical advection, even though the measured integrated fluxes indicated that there had been considerable sediment focusing. Recent measurements of Cs-137 and Pb-210 in sediment cores from Green Bay in Lake Michigan and least-squares best fits for sedimentation rates and mixing depths from these data suggest that these simple models are incorrect and do not adequately reflect the resuspension, horizontal transport, and redeposition of bottom sediments. Furthermore, such processes are not confined to shallow water; a comparison of total Cs-137 content, sedimentation rates, and mixing depths measured in a series of cores taken from Lake Michigan at the same locations 10 years apart indicate that while the overall integrated Cs-137 content of the sediments, corrected for radioactive decay, has remained constant, there has been an increase within and a decrease at the periphery and outside of the depositional zones. Over the same period there was, as would be predicted from the simple models, an increase in the thickness of the measured mixing depth.

GL-012

Evans, M.S., and P.F. LANDRUM. Toxicokinetics of DDE, Benzo(a)pyrene, and 2,4,5,2',4',5'-Hexachlorobiphenyl in Pontoporeia hoyi and Mysis relicta. Journal of Great Lakes Research 15(4):589-600 (1989).

The toxicokinetics of DDE, benzo(a)pyrene (BaP), and 2,4,5,2',4',5'-hexachlorobiphenyl (HB) were followed for the amphipod, Pontoporeia hoyi, and the mysid Mysis relicta. Pontoporeia and Mysis had similar uptake clearances (K_1) for DDE (mean = 79.2 mL/g/h and 46.0 mL/g/h, respectively), BaP (mean = 75.9 mL/g/h and 39.9 mL/g/h, respectively), and HB (mean = 53.5 mL/g/h and 57.5 mL/g/hr, respectively) compounds with log octanol-water partition coefficients (K_{ow}'s) ranging from 5.7 to 6.7. Amphipods and mysids were most efficient at eliminating BaP (mean K_2 = -0.0017/h and -0.0047/h, respectively) and least efficient at eliminating HB (mean = -0.0008/h and -0.0001/h respectively). Amphipods were more efficient than mysids in eliminating DDE (mean = -0.0010/h and -0./0005/h, respectively) and HB while mysids were more efficient at eliminating BaP. Because K_2's for DDE, BaP, and HB were substantially different between P. hoyi and M. relicta, there were substantial differences in the calculated bioconcentration factors (BCFs). Amphipods tended toward larger BCFs than mysids for BaP (mean = 48,582 and 8,496, respectively) but lower BCFs for DDE (mean = 95,629 and 138,760, respectively) and HB (mean = 101,663 and 442,231, respectively) than mysids.

GL-013

FAHNENSTIEL, G.L., J.F. CHANDLER, H.J. CARRICK, and D. SCAVIA. Photosynthetic characteristics of phytoplankton communities in Lakes Huron and Michigan: P-I parameters and end-products. Journal of Great Lakes Research 15(3):394-407 (1989).

Photosynthetic-irradiance (P-I) curves and partitioning of photosynthate into major end-products (protein, lipids, polysaccharides, and low molecular weight [LMW] metabolites) were examined for phytoplankton communities from Lakes Huron and Michigan. The mean and variance of P-I parameters and photosynthetic end-products were similar in both lakes. Mean P_M^B (maximum light saturated rate) and α (initial linear slope) values were 2.3 mg C•mg Chl^{-1}•h^{-1} and 5.5 mg C•mg Chl^{-1}•$Einst^{-1}$•m^2 for Lake Huron communities, and 2.4 mg C•mg Chl^{-1}•h^{-1} and 7.0 mg C•mg Chl^{-1}•$Einst^{-1}$•m^2 for Lake Michigan communities. The mean percent incorporation of $^{14}CO_2$ into proteins, lipids, polysaccharides, and LMW metabolites from short-term experiments (2-4 h) were 32.4, 21.3, 28.0, and 18.9, respectively, for Lake Huron communities and 34.8, 24.7, 24.5, and 15.8, respectively, for Lake Michigan communities. Over longer incubations the activity in each end-product increased linearly during the day; during the night the activity in the LMW and polysaccharide fractions decreased and the activity in the protein fraction increased. There were significant seasonal variation in P-I parameters and the photosynthetic end-products. In both lakes, phytoplankton communities from the late winter-spring isothermal period were characterized by lower P_M^B values, higher α values, significant susceptibility to photoinhibition, and less incorporation into protein, as compared to communities from periods when the lakes were thermally stratified.

GL-014

GARDNER, W.S., P.F. LANDRUM, and J.F. CAVALETTO. Lipid-partitioning and disposition of benzo(a)pyrene and Hexachlorobiphenyl in Lake Michigan Pontoporeia hoyi and Mysis relicta. Environmental Toxicology and Chemistry 9:1269-1278 (1990).

Two Lake Michigan macroinvertebrates, Pontoporeia hoyi and Mysis relicta, exhibited major differences in the disposition of the lipophilic contaminants, [^{3}H]benzo(a)pyrene (BaP) and [^{14}C]2,4,5,2',4',5'-hexachlorobiphenyl (HCB). Interactions of these contaminants with major lipid classes (triacylglycerols and phospholipids) were examined by centrifuging aqueous whole organism homogenates of labeled animals into three discrete layers that were operationally defined as "buoyant-lipid," "particle" and "aqueous" fractions. The buoyant-lipid fraction contained most of the energy storing triacylglycerols, whereas the particle and aqueous fractions contained most of the membrane phospholipids. During 2 to 4 d experiments, unmodified BaP and HCB partitioned among the three fractions in proportion to the distribution of total-lipids in both species, but in M. relicta most of the BaP was biotransformed into polar metabolites that were selectively found in the aqueous and particle fractions. Apparently HCB was not substantially biotransformed in either species but took longer (ca. 2 d) to reach steady state among lipid pools in M. relicta than it did in P. hoyi (<1 d). Although the contaminants did not always completely reach steady state in the organisms with respect to the external environments during these relatively short experiments, they appeared to reach steady state among lipid pools within the organisms.

GL-015

GARDNER, W.S., M.A. QUIGLEY, G.L. FAHNENSTIEL, D. SCAVIA, and W.A. Frez. Pontoporeia hoyi - a direct trophic link between spring diatoms and fish in Lake Michigan. In Large Lakes: Ecological Structure and Function, M.M. Tilzer and C. Serruya (eds.). Springer-Verlag, New York, 632-644 (1990).

Several lines of evidence suggest that the Lake Michigan benthic amphipod, Pontoporeia hoyi (an important fish prey in large, temperate, low-nutrient lakes), may obtain a large portion of its annual energy directly from the spring diatom bloom: 1) Energetic considerations suggest that P. hoyi must assimilate a large fraction of energy from incoming organic material, but that summer input rates are not sufficient to support observed annual production of P. hoyi. 2) The weight-specific lipid content of P. hoyi at some locations in Lake Michigan doubles within a few weeks after the spring diatom bloom. 3) Lipids accumulate in P. hoyi primarily as the storage products, triglycerides. 4) P. hoyi feeds intermittently and can survive for months without food. 5) The dominant spring diatom in Lake Michigan, Melosira, is not significantly cropped by zooplankton and settles rapidly through the water column in the spring and early summer. 6) After the spring diatom bloom, the phytoplankton changes to a dominance of flagellates that are mostly eaten by pelagic zooplankton and therefore largely unavailable to benthic organisms. The ability of P. hoyi to rapidly accumulate and store energy from spring diatom blooms may help explain why this amphipod thrives in many temperature, oligotrophic/mesotrophic lakes. This apparently direct trophic linkage between spring diatoms and P. hoyi is energetically important because it involves a minimum of trophic energy loss between primary production and fish.

GL-016

GOTTLIEB, E.S., J.H. SAYLOR, and G.S. MILLER. Currents and temperatures observed in Lake Michigan from June 1982 to July 1983. NOAA TM ERL GLERL-71 (PB90-131921/XAB), 47 pp. (1989).

An array of 15 moorings, supporting current meters at 15 and 50 m depths, was in place in Lake Michigan from June 1982 to July 1983. Six moorings surrounded the southern basin on about the 75 m isobath, six closely spaced moorings transected the mid-lake ridge and adjacent valley, and three moorings occupied the centers of the southern and northern basins. In the southern basin, monthly-averaged currents are weakly anticyclonic during June and July, cyclonic during the rest of the year, and most intense during March. Temperatures and bidaily-averaged currents both show the effects of the gravest (4-day period) vortex-mode oscillation. Also, it is shown that the seasonal thermocline became well established much earlier in 1983 (early June) than in 1982 (middle August).

GL-017

GOTTLIEB, E.S., J.H. SAYLOR, and G.S. MILLER. Currents, temperatures, and divergences observed in eastern central Lake Michigan during May-October 1984. NOAA TM ERL GLERL-72 (PB90-131194/XAB), 48 pp. (1989).

An array of four instrumented moorings covering an area of 150 km^2 was in place approximately 40 km offshore in eastern central Lake Michigan during May-October 1984. Each mooring supported current meters at the depth levels 5, 10, 20, 30, 50, and 100 m, and a thermistor chain between 6 and 46 m depth. The current velocity data were used to compute the divergence and curl across the array area at each depth level. Two or three events of large southeastward currents, north-south alternating wind bursts, upwelled thermocline, and increased positive divergence and negative curl were observed from mid-August to early September.

GL-018

GREAT LAKES ENVIRONMENTAL RESEARCH LABORATORY. Annual Report for the Great Lakes Environmental Research Laboratory, FY 88. Great Lakes Environmental Research Laboratory, Ann Arbor, MI, 64 pp. (1990).

No abstract.

GL-019

GREAT LAKES ENVIRONMENTAL RESEARCH LABORATORY. Annual Report for the Great Lakes Environmental Research Laboratory, FY 89. Great Lakes Environmental Research Laboratory, Ann Arbor, MI, 53 pp. (1990).

No abstract.

GL-020

HARTMANN, H.C., and M.J. Donahue. The institutional morass: Constraints and opportunities for issue management. Proceedings, International and Transboundary Water Resources Issues, Toronto, Ontario, Canada, April 1-5, 1990. American Water Resources Association, 329-338 (1990).

A critical link exists between government policies and the institutional milieu which exists to fulfill those policies. Ostensibly, the large number of institutions which influence use of the Great Lakes leads to public confusion and a perception of institutional unresponsiveness. However, the current institutional setting is actually a rational response to several characteristics inherent to the Great Lakes system and government behavior; elimination of institutions simply to reduce the number of players is inappropriate. Rather, the exclusive and adversarial

nature of traditional agency decisionmaking processes appears to be a pivotal problem. Future planning must incorporate Alternative Dispute Resolution (ADR) processes, which seek to build consensus among the various interest groups (agencies included) that have some stake in Great Lakes management decisions. For many contentious Great Lakes issues, ADR uniquely offers the potential for mutual learning by groups as their assumptions and perceptions are evaluated by other groups during facilitated policy dialogues, collaborative problem-solving, or negotiations.

GL-021

HAWLEY, N., and J.E. ZYREN. Transparency calibrations for Lake St. Clair and Lake Michigan. Journal of Great Lakes Research 16(1):113-120 (1990).

Extensive measurements of water transparency using a Sea Tech transmissometer and total suspended solids (TSM) were made in the southern basin of Lake Michigan and in Lake St. Clair. The relationship between transparency and TSM in each lake can be expressed very well by a single equation. The similarity in the slopes of the lines for two lakes suggests that the physical properties of the particles suspended in the water are very similar, while the large difference between the intercepts is due to the presence in Lake St. Clair of very fine material (particle diameter less than one micron) which is not present in Lake Michigan. Attempts to use the transparency measurements to identify different particle populations in Lake Michigan as a function of time, station, and sample depth were unsuccessful. Limited data from northern Lake Michigan, Lake Huron, and Lake Superior suggest that the material in Lake Huron is similar to that in the southern basin of Lake Michigan while the observations in northern Lake Michigan more closely resemble those from Lake Superior.

GL-022

Holland, R.E., A.M. BEETON and T.H. JOHENGEN. Saline Valley rural clean water project interim report on monitoring during 1988. Contract report, Michigan Department of Agriculture, Washtenaw County Board of Commissioners, the Monroe County Board of Commissioners, the Washtenaw County Soil Conservation District, and the Monroe County Soil and Water Conservation District, 85 pp. (1989).

No abstract.

GL-023

JOHENGEN, T.H., A.M. BEETON and R.E. Holland. Saline Valley rural clean water project interim report on monitoring during 1989. Contract report, Michigan Department of Agriculture, Washtenaw County Board of Commissioners, the Monroe County Board of Commissioners, the Washtenaw County Soil Conservation District, and the Monroe County Soil and Water Conservation District, 78 pp. (1990).

No abstract.

GL-024

KEILTY, T.J. Note. Evidence for Alewife (Alosa pseudoharengus) predation on the European cladoceran Bythotrephes cederstroemi in northern Lake Michigan. Journal of Great Lakes Research 16(2):330-333 (1990).

Stomach contents of 10 alewife (Alosa pseudoharengus) 3 bloaters (Coregonus hoyi), 1 rainbow smelt Osmerus mordax), 4 chinook salmon (Oncorhynchus tshawytscha), and 1 lake trout (Salvelinus namaycush) were examined for the presence of the European cladoceran, Bythotrephes cederstroemi. Fish were collected commercially (by gillnetters and sport charters) in July and August of 1988 in the North Manitou Island area of Lake Michigan when B. cederstroemi were abundant. The zooplankter was found in all alewife examined and its remains normally filled the entire stomach cavity. The only other evidence for fish predation on B. cederstroemi was found in the stomach from a 0.5 kg chinook salmon. A few caudal spine fragments were found in the stomach of one bloater yet because the stomach was full of the benthic amphipod, Pontoporeia hoyi, it was hypothesized that the fish acquired the remains from the sediments. Stomachs of other fish were either empty or did not contain B. cederstroemi. Although limited, these data are the first conclusive evidence that the economically important alewife prey upon the exotic B. cederstroemi in the open waters of the Great Lakes.

GL-025

KEILTY, T.J., and P.F. LANDRUM. Population-specific toxicity responses by the freshwater oligochaete, Stylodrilus heringianus, in natural Lake Michigan sediments. Environmental Toxicology and Chemistry 9:1147-1154 (1990).

Sediment reworking rate, mortality and organisms dry weight were measured for Stylodrilus heringianus in laboratory microcosms. The experiments were designed to identify potential population-specific response differences to mixed (stirred to obtain a more uniform particle size distribution over depth) and unmixed (passively settled) microcosm sediments. Lake Michigan sediments and worms were collected offshore Benton Harbor, Michigan and Grand Haven, Michigan. The mixed Benton Harbor sediments were toxic to S. heringianus collected from Grand Haven, whereas there were no significant differences in measured responses between mixed and unmixed sediment microcosms for Grand Haven-collected worms exposed to Grand Haven sediments or Benton Harbor -collected worms exposed to Benton Harbor sediments.s Note that the mixing of sediments resulted in increased availability of contaminants sorbed to the fine sediment fraction. Because contaminant and

oligochaete population density data suggest that Grand Haven sediments are less contaminated, the population-specific response suggests that S. heringianus may adapt to the low level long-term stressful conditions (chemical or otherwise). Results also suggest caution and consideration of the history of test organisms in the design and interpretation of toxicity tests.

GL-026

LAIRD, G.A., and D. SCAVIA. Distribution of labile dissolved organic carbon in Lake Michigan. Limnology and Oceanography 35(2):443-447 (1990).

Bioassay-measured, labile dissolved organic carbon (LDOC) concentrations were compared in near-bottom and near-surface Lake Michigan water between April and October 1986. In five of seven experiments, the LDOC concentration was higher in near-bottom water. LDOC reached 40.2% of the total DOC pool in the near-bottom water in late May and 13.8% in the near-surface water in early July. Concentration in near-bottom water was highest during early stratification; concentration in surface water varied less but was highest in early July. The data suggest that an allochthonous source of labile organic C may be important.

GL-027

LAIRD PERNIE, G., D. SCAVIA, M.L. Pace, and H.J. CARRICK. Micrograzer impact and substrate limitation of bacterioplankton in Lake Michigan. Canadian Journal of Fisheries and Aquatic Science 47:1836-1841 (1990).

We estimated Lake Michigan epilimnetic heterotrophic bacterial loss rates, predator size, and substrate limitation in 1986 and 1987. The bacterial growth rates were always enhanced by organic substrate additions indicating that bacterial growth is limited, to some degree, by substrate availability. In this study we obtained loss rates and intrinsic growth rates each between 0.32 and 1.45 d-1. The grazers were predominantly picoplankton-size organisms, presumably heterotrophic flagellates. Using radiolabeled bacteria, only a small percentage (2-3%) of bacterial cells were incorporated in larger size fractions after 24 h. These results indicate that during our experiments heterotrophic bacteria were not a direct, significant, carbon source for t he upper trophic levels.

GL-028

LANDRUM, P.F. and J.A. ROBBINS. Bioavailability of sediment-associated contaminants to benthic invertebrates. In Sediments: Chemistry and Toxicity of In-Place Pollutants, R. Baudo, J.P. Giesy, and H. Muhtau (eds.). Lewis Publishers, Inc., Chelsea, MI, 237-263 (1990).

No abstract.

GL-029

LANG, G.A., and T.D. FONTAINE, III. Modeling the fate and transport of organic contaminants in Lake St. Clair. Journal of Great Lakes Research 16(2):216-232 (1990).

Despite the rapid hydraulic turnover time of Lake St. Clair, inputs of organic contaminants to the lake are a cause for concern because of their potential long-term storage in the lake's surficial sediments. In order to understand and predict the transport and fate of organic contaminants in Lake St. Clair, a multisegment, contaminant mass balance model was developed. The model was calibrated and tested against four data sets that describe the behavior of the conservative chloride ion, and against two data sets that describe the fate and distribution of sediment-bound cesium-137. Model applications included simulations of octachlorostyrene (OCS) and polychlorinated biphenyl (PCB) dynamics in the lake. The model predicted that during 1971-83, 3.8 MT of OCS entered the lake, 2.8 MT were flushed from the system, 0.8 MT were lost due to biological degradation and volatilization, and 0.2 MT remained in the system. The model also predicted that during 1970-74, 3.4 MT of PCB entered the lake, 2.1 MT were flushed from the system, 2.2 MT were lost due to biological degradation and volatilization, and the system mass of PCB decreased from 1.9 to 1.0 MT.

GL-030

LESHKEVICH, G.A. Diurnal patterns of the bi-directional reflectance of fresh-water ice. Annals of Glaciology 14:153-157 (1990).

To improve the interpretation of surface cryospheric albedo from satellite sensor data, diurnal measurements of the spectral bi-directional reflectance of a commonly-found fresh-water ice type were made, from which hemispherical reflectance can be derived. The purpose of this study is to document its clear-sky, bidirectional reflectance characteristics in the visible (650-670 nm) and near-infrared (810-840 nm) region, assess the diurnal nature of the reflectance, and quantify the surface anisotropy. Bi-directional reflectances of the re-frozen slush ice measured show a spectral dependence and change significantly with solar zenith angle. Considerable variation occurs at each view angle and among view angles throughout the day. Although diurnal reflectance patterns were similar in both bands, the magnitudes varied greatly, being highest in the visible and lowest in the near-infrared region. With the exception of peak saturated (specular) values in the forward scatter direction, bi-directional reflectance was generally highest in the morning when the surface and the illumination were most diffuse in character. The exitance (πN) computed from nadir radiance (N) is compared to the measured hemispheric exitance (M). The $\pi N/M$ ratio, an index of anisotropy, reveal an anisotropy that increases with increasing solar zenith angle and is more pronounced in the near-infrared region.

GL-031

LINDNER, S.R. Sorption of volatile organic compounds and their mixtures on synthetic and natural soils. Ph.D. dissertation, Cornell University, Ithaca, NY, 230 pp. (1990).

Although sorption can have a profound influence on the fate of chlorinated hydrocarbon solvents and hydrocarbon fuels, the sorptive behavior of volatile organic compounds in unsaturated soils is relatively untested. A headspace analysis technique was used to measure the partitioning of 15 volatile organic compounds between the vapor phase and a synthetic soil sorbent made by coating aluminum oxide with Aldrich humic acid. The sorptive behavior of the 15 organic compounds was related to their physical/chemical properties to deduce sorbate properties which influence sorption from the vapor phase. since fuels and solvents are commonly introduced to the environment as component mixtures, a second objective was to study the behavior of sorbate mixtures. The effect of sorbent moisture content on observations was also considered.

GL-032

MILLER, G.S., R.W. MUZZI, J.E. DUNGAN, and J.H. SAYLOR. Technical Note. Adding LORAN-C position recording to a satellite-tracked drifter buoy. MTS Journal 23(3):36-38 (1989).

A LORAN-C receiver-recording system was designed and embodied in a satellite-tracked drifter buoy. The purpose of the system is to obtain more accurate, uniformly-spaced times series of Lagrangian current measurements. LORAN-C positions, clock counter, receiver status, and other ancillary data are recorded on a data storage module on board the buoy. Depending on battery capacity, minimum deployments of twelve to forty-four days can be expected for sampling rates of ten to sixty minutes.

GL-033

NALEPA, T.F. Estimates of macroinvertebrate biomass in Lake Michigan. Journal of Great Lakes Research 15(3):437-443 (1989).

To obtain updated, more accurate estimates of macroinvertebrate standing stocks in Lake Michigan, benthic biomass (ash-free dry weight) was determined at 40 stations in the southern end of the lake in 1980 and 1981. Biomass generally increased as sampling depth increased from 16 to 30 m, peaked at depths of 30-40 m, and then declined at depths greater than 40 m. Mean total biomass at the 16-30 m, 31-50 m, 51-90 m, and > 90 m depth intervals was 4.9, 7.8, 4.2, and 1.9 g m^{-2}, respectively. Oligochaetes (46%) and Pontoporeia hoyi (44%) accounted for most of the biomass at depths shallower than 30 m, but P. hoyi was the dominant form (65%) at depths greater than 30 m. Differences in total biomass between years and seasons (spring, summer, fall) were not significant, but year X season interaction was significant at depths greater than 30 m. Mean biomass in the profundal of southern Lake Michigan (> 90 m) was over twice that found in the profundal of either Lakes Superior, Huron, or Ontario.

GL-034

QUIGLEY, M.A., J.F. CAVALETTO, and W.S. GARDNER. Lipid composition related to size and maturity of the amphipod Pontoporeia hoyi. Journal of Great Lakes Research 15(4):601-610 (1989).

Micro-gravimetric determination of the lipid content of amphipods (Pontoporeia hoyi) obtained from a 45-m-deep Lake Michigan sampling site indicated that the mean lipid content of adult females was 30% on a non-lipid dry weight (NLDW) basis, and that juveniles and adult males contained 21 and 10% lipid (NLDW basis), respectively. Thin layer chromatography-flame ionization detection (TLC-FID) analyses revealed that lipids of females were composed primarily of triacylglycerols (81%), the principal energy storage lipid of amphipods. Lipids of juveniles were composed largely of triacylglycerols (41%) and phospholipids (44%). Adult male P. hoyi lipids consisted mostly of phospholipids (64%) and, secondarily, of triacylglycerols (12%). The relatively low triacylglycerol concentrations in males may be associated with the minimal requirements for energy stores to support metabolic needs during the male's brief (10 day) life span. By contrast, the high lipid content and marked abundance of triacylglycerols in adult females represents an important energy store supporting subsequent egg development, particularly since females appear to halt all feeding upon maturation. In juvenile P. hoyi, increased individual size (NLDW) was accompanied by increased lipid dry weight, implying that juveniles accumulate lipids during growth. Overall, the results demonstrated the importance of considering P. hoyi size, life stage, and sex when describing a population's lipid content or composition. This consideration is particularly critical when evaluating the role of P. hoyi in the transfer of energy and/or organic contaminants within the Great Lakes food web.

GL-035

QUINN, F.H., and C.E. SELLINGER. Note. Lake Michigan record levels of 1838, a present perspective. Journal of Great Lakes Research 16(1):133-138 (1990).

Record high lake levels for this century, set for all lakes but Ontario in 1985 and 1986, caused extensive economic losses and were a major concern of riparian interests. An analysis of early Lake Michigan-Huron water levels recorded at Milwaukee, Wisconsin, beginning in 1819 revealed an extremely high lake level regime peaking in 1838. To provide a valid comparison with recent data, the 19th century data were first adjusted to the International Great Lakes Datum of 1955 and corrected for differential isostatic rebound between Milwaukee and the outlet water level gage for Lake Michigan-Huron at Harbor Beach, Michigan. A comparison of the 1838 lake levels with the recent records indicates the former to be approximately 50 cm higher than the record set in 1986. A future recurrence of the climatic conditions causing the 1838 high lake

levels would have a severe outcome for riparian interests throughout the Great Lakes region.

GL-036

ROBBINS, J.A., A. Mudroch, and B.G. Oliver. Transport and storage of ^{137}Cs and ^{210}Pb in sediments of Lake St. Clair. Canadian Journal of Fisheries and Aquatic Sciences 47(3):572-587 (1990).

In 1985 cores were collected by diver from areas with fine-grained sediments in Lake St. Clair. Although the lake is shallow, rapidly flushed, and possesses only a thin layer of postglacial sediment (ca. 30 cm max.), 8% of the estimated ^{137}Cs loading from atmospheric nuclear testing in the mid-1960s and 13% of the potential standing crop of excess ^{210}Pb were retained. A sediment column transport model including eddy diffusive mixing, advection, and resuspension, acceptably described the vertical distribution of these radionuclides as well as stable lead and implied that such efficient retention may be of recent origin, occurring with the onset of net sedimentation about 100 yr ago. The model showed that, at selected sites, the history of lake loading by particle-associated contaminants can be reconstructed from sediment profiles. Horizontally averaged characteristics of the deposit indicate a surface mixed layer mass of 5 gcm^{-2} and tracer residence time of 3 yr in accord with residence times of surficial Hg, PCBs, and DDT. Trap-collected materials from two sites show markedly contrasting seasonal variations in ^{137}Cs activity reflecting differing proportions of particles derived from inflow (ca 300 $mBq\,g^{-1}$) and resuspension (<30 $mBq\,g^{-1}$).

GL-037

Shabman, L., B. Smit, W. Shoots, L. Ludlow, K. O'Grady, H.C. HARTMANN, and C. Stewart. Living with the Lakes: Challenges and Opportunities, Annex C: Interests, Policies, and Decision Making: Proposects for Managing the Water Levels Issue in the Great Lakes - St. Lawrence River Basin. International Joint Commission, Washington, DC, 153 pp. (1990).

No abstract.

GL-038

STEHLY, G.R., and W.L. Hayton. Effect of pH on the accumulation kinetics of pentachlorophenol in goldfish. Archives of Environmental Contamination and Toxicology 19:464-470 (1990).

The kinetics of accumulation of pentachlorophenol (PCP) at various pH values were investigated to explore how pH-dependent accumulation might influence PCP toxicity. Goldfish (Carassius auratus) were exposed to 5 µg PCP/L in a static system buffered with 7.5 mM bicine or N,N-bis(2-hydroxyethyl)-2-aminoethane sulfonic acid (BES) at pH 7.0, 8.0, or 9.0. The amount of PCP in the fish, concentration of PCP in water, and the total amount of metabolites in the system were measured after exposure of fish from 1 to 96 h. Equations for these variables based on a two compartment pharmacokinetic model were fitted simultaneously to the data using NONLIN, which uses an iterative nonlinear least squares computer technique. Uptake clearance, metabolic clearance, and apparent volume of distribution of PCP decreased as pH increased. The decrease in PCP accumulation with increased pH was not due solely to a pH induced decrease in uptake. In addition, the distribution of PCP within the fish was altered by changes in the external pH. The pH-associated changes in distribution may have altered access of PCP to sites of metabolism, thereby altering the metabolic clearance. The pH-related changes in the pharmacokinetics of PCP resulted in a decrease in its bioconcentration factor with an increase in pH and account both for the decreased capacity of the fish to accumulate PCP and for its reduced LC50.

GL-039

STEHLY, G.R., P.F. LANDRUM, M.G. Henry, and C. KLEMM. Toxicokinetics of PAHs in Hexagenia. Environmental Toxicology and Chemistry 9:167-174 (1990).

The accumulation kinetics of two water-borne polycyclic aromatic hydrocarbons (PAHs), benzo(a)pyrene (BAP) and phenanthrene (PHE), were studied in the mayfly nymph (Hexagenia limbata). The uptake clearance decreased while the bioconcentration of BAP increased with an increase in the weight of the H. limbata nymph. The relationship between uptake clearance and bioconcentration for PHE was variable, and bioconcentration was greater for the heavier animals. Two kinetic models were used to evaluate the nymph weight on disposition of PAHs: (a) the amount-uptake clearance model, similar to models most frequently used in environmental toxicology; and (b) a clearance-volume model, similar to models used in clinical pharmacology. The two models gave similar predictive results but were different in a few cases. These differences in common parameter estimation probably resulted from methodologies used and high data variability rather than the models themselves, since they are mathematically equal. Some of the parameters are unique to each of the models defined and described. The clearance of oxygen from water is inversely and linearly related to the weight of the mayfly nymphs, but oxygen clearances were always much less than the uptake clearances of the PAHs. The high PAH uptake clearance compared to oxygen clearance implies a greater surface area or efficienty for PAH accumulation from water.

GL-040

TARAPCHAK, S.J., and R.A. Moll. Phosphorus sources for phytoplankton and bacteria in Lake Michigan. Journal of Plankton Research 12(4):743-758 (1990).

Size-fractionation experiments on the uptake of phosphate (PO^4) and recently excreted dissolved organic phosphorus (E-DOP) from

phytoplankton suggest that algae and bacteria rely on different forms of phosphorus (P) in the epilimnion of P-limited Lake Michigan. Rate constants for PO_4^{3-} uptake on 0-1 μm fractions generally were low relative to those measured in wholewater, suggesting that most of the uptake was by algae. Uptake of ^{32}P-E-DOP in 0-1 μm fractions approximated uptake in wholewater, indicating uptake principally by bacteria. Concurrent experiments showed that (i) E-DOP and PO_4^{3-} were taken up by different transport systems; (ii) bacteria have transport systems for E-DOP compounds; and (iii) cell-surface phosphatase-mediated PO_4^{3-} supply to phytoplankton from E-DOP was negligible. Results suggest that pathways of PO_4^{3-} and E-DOP flux in microplankton communities of P-limited large and small lakes may differ. The use of different sources of P by algae and bacteria in Lake Michigan supports the classical concept of algal-bacterial freshwater P cycling. These findings are consistent with a proposed hypothesis that, in large lakes with low allochthonous nutrient inputs, phytoplankton are P-limited and use PO_4^{3-}, while bacteria obtain P primarily from dissolved organic compounds and are limited by a nutrient other than P.

GL-041

VANDERPLOEG, H.A., G.-A. Paffenhofer, and J.R. LIEBIG. Concentration-variable interactions between calanoid copepods and particles of different food quality: observations and hypotheses. In Behavioural Mechanisms of Food Selection, R.N. Hughes (ed.). Springer-Verlag, Berlin Heidelberg, NATO ASI Series, Vol. G20, 595-613 (1990).

No abstract.

Addendum

GL-042

GREAT LAKES ENVIRONMENTAL RESEARCH LABORATORY. Annual Report for the Great Lakes Environmental Research Laboratory, FY 86-87. Great Lakes Environmental Research Laboratory, Ann Arbor, MI, 61 pp. (1989).

No abstract.

GL-043

HARTMANN, H.C., and F.H. QUINN. Climatic extremes and Great Lakes water management. Proceedings, VIth IWRA World Congress on Water Resources, Vol. II, Ottawa, Ontario, Canada, May 28-June 3, 1988. International Water Resources Association, Urbana, IL, 476-485 (1988).

Historical climatic conditions suggest that the typical climate of the North American Great Lakes region is much cooler and wetter than the regime experienced during the mid-twentieth century. However, anthropogenic increases in greenhouse gases may cause a climatic warminig in the next 50 years. A model of the hydrologic response of the Great Lakes was used with a range of hydrometeorological scenarios to provide a perspective on the potential for water level variations and possible water management strategies. Climatic shifts, whether cooler or warmer, will require new paradigms of how the Great Lakes will be viewed from social, economic, and ecological perspectives.

GL-044

Holland, R.E., A.M. BEETON and T.H. JOHENGEN. Saline Valley rural clean water project interim report on monitoring during 1987. Contract report, Michigan Department of Agriculture, Washtenaw County Board of Commissioners, the Monroe County Board of Commissioners, the Washtenaw County Soil Conservation District, and the Monroe County Soil and Water Conservation District, 117 pp. (1988).

No abstract.

GL-045

SCAVIA, D., and G.L. FAHNENSTIEL. From picoplankton to fish: Complex interactions in the Great Lakes. In Complex Interactions in Lake Communities, S.R. Carpenter (ed.). Springer-Verlag, New York, 85-97 (1988).

No abstract.

NATIONAL SEVERE STORMS LABORATORY

NS-001

Antolik, M. A., and C. A. DOSWELL III. On the contribution to model-forecast vertical motion from quasi-geostrophic processes. Preprints, 12th Conference on Weather Analysis and Forecasting, Monterey, CA, October 2-6, 1989. American Meteorological Society, Boston, 312-318 (1989).

No abstract.

NS-002

AUGUSTINE, J.A., E. TOLLERUD, and B. JAMISON. Distributions and other general characteristics of mesoscale convective systems during 1986 as determined from GOES infrared imagery. Preprints, 12th Conference on Weather Analysis and Forecasting, Monterey, CA, October 2-6, 1989. American Meteorological Society, Boston, 437-442 (1989).

No abstract.

NS-003

Balakrishnan, N. and D.S. ZRNIC. Estimation of rain and hail rates in mixed-phase precipitation. Journal of the Atmospheric Sciences 47: 565-583 (1990).

Precipitation comprising rain and hail is studied. Specifically, techniques to identify and quantify such precipitation in terms of rain and hail fall rates using dual polarized radar data, are presented. Included for consideration are Z_H, the reflectivity factor for horizontal polarization, Z_{DR}, differential reflectivity, and K_{DP}, the differential propagation constant. A variety of simple models of mixed-phase precipitation are first examined. Electromagnetic scattering computations are performed to simulate and study the behavior of Z_H, Z_{DR}, and K_{DP}. It is shown that it is possible to distinguish the mixed-phase precipitation from either rain or hail by using Z_H, K_{DP} pairs and also to infer the thermodynamic phase and orientation from Z_H Z_{DR}. On the basis of physical principles, it is shown that D_{DP} senses primarily liquid water in the form of raindrops even when these are mixed with hailstones. The self-consistency of Z_H, Z_{DR} and K_{DP} is then exploited to estimate both the rain and hail fall rates. The ability of the methods to estimate rain and hail fall rates is demonstrated with actual radar data from two Oklahoma storms.

NS-004

Balakrishnan, N., and D.S. ZRNIC. Use of polarization to characterize precipitation and discriminate large hail. Journal of the Atmospheric Sciences, 47: 1525-1540 (1990).

We examine the utility of the correlation coefficient between linear orthogonally polarized echoes for determining precipitation type and gauging hail size. Models and measurements from pure rain coincide in predicting very high correlations (0.98); similar results are obtained with pure hail. Several mechanisms could cause the lowering of correlation but the behavior of the examined data is definitely attributed to a mixture of hydrometer types. This decrease is an indicator of hail size; it is shown theoretically that in at least two other realistic situations the correlation would decrease with hail size. For the examined case a model of hail shape and orientation during fall is able to reproduce the essential features of polarimetric measurements. It suggests together with our data and data from other investigators, that substantial negative differential reflectivity (about -1 dB) in a region of high reflectivity factor values is caused by hailstones larger than about 2 cm in diameter.

NS-005

BARTELS, D.L., and R.A. MADDOX. A satellite based climatology of mid-level cyclonic vortices generated by mesoscale convective complexes. Preprints, 12th Conference on Weather Analysis and Forecasting, Monterey, CA, October 2-6, 1989. American Meteorological Society, Boston, 87-92 (1989).

No abstract.

NS-006

BLANCHARD, D.O. Mesoscale convective patterns of the southern High Plains. Bulletin of the American Meteorological Society 71:994-1005 (1990).

Mesoscale convective systems observed in the southern High Plains during the Oklahoma-Kansas Preliminary Regional experiment for STORM-central (PRE-STORM) field program were analyzed using radar and rawinsonde data. Although radar data indicate that no two systems are identical, basic recurring mesoscale structures are evident. Based on these recurrent features, the systems have been classified into three types of mesoscale convective patterns: linear mesoscale systems, occluding mesoscale systems, and chaotic mesoscale systems. Examples of all three types are discussed. High-density rawinsonde data collected in the regions ahead of the mesoscale systems have been averaged to produce composite soundings; the composites exhibit differences in both thermodynamic and wind structure between types.

NS-007

Bluestein, H.B., E.W. McCaul, Jr., G.P Byrd, R.L. Walko and R.P. DAVIES-JONES. An observational study of splitting convective clouds. Monthly Weather Review 118: 1359-1370 (1990).

This is a case study of deep, but narrow convective towers which split twice into right- and left-moving components in southwestern Oklahoma on 28 May 1985. Our analysis makes use of storm-intercept visual documentation, mobile soundings, surface mesonetwork data, and frequent soundings from special sites. The data show that the convective towers behaved in many respects like low-precipitation storms, having formed in an environment of large CAPE and moderately strong unidirectional shear. The observation of towers splitting even when there is no heavy precipitation at the surface implies that rain processes are not crucial to the splitting phenomenon. The tiny storms were confined to a region northeast of a surface cyclone and low-pressure area, near the intersection of the dryline and outflow boundary, where convective temperature was reached. Evidence is presented that the moist layer was deepened locally just prior to convective initiation, and that the deepening was related to low-level convergence associated with westward motion of the dryline.

NS-008

BRANDES, E.A. Evolution and structure of the 6-7 May 1985 mesoscale convective system and associated vortex. Monthly Weather Review 118: 109-129 (1990).

Observations collected during the Oklahoma-Kansas PRE-STORM experiment are used to document the evolution and structure of the mesoscale convective system (MCS) that occurred on 6-7 May 1985. The storm began when a short squall line developed in an area of preexisting thunderstorm activity. Thunderstorm updrafts along the squall line lifted warm, moist air with its southerly momentum to the upper troposphere. A broad region of convective outflow and a meso-β-scale updraft region with a mean vertical velocity in excess of 15×10^{-3} mb s^{-1} were created. A stratiform rain area with an embedded mesovortex formed behind the squall line. The vortex resided beneath the deepest upper-level outflow. The mesovortex altered the wind field and consequently became the principal organizational feature within the MCS. A descending current from the storm's rear that, depending on location, extended from 1 km to the upper troposphere was intensified and focused by the vortex. The descending rear inflow had a peak vertical velocity of 10×10^{-3} mb s^{-1} and concentrated into a jet that passed to the south of the vortex. The intruding flow caused the precipitation and cloud fields to develop comma-like shapes and determined the distribution of kinematic parameters within the MCS. Mesovortex vertical vorticity was a maximum (25×10^{-5} s^{-1}) at middle-storm levels where environmental air converged into the mesoscale downdraft but was also strong at lower levels where the mesoscale downdraft dominated. Stretching of preexisting vorticity seems the primary amplification mechanism at middle levels. Tilting of horizontal vorticity generated by baroclinicity in the rear inflow is given as an explanation for the low-level vorticity.

NS-009

BURGESS, D.W., and L.R. Lemon. Severe thunderstorm detection by radar. In Radar in Meteorology Battan Memorial and 40th Anniversary Radar Meteorology Conference, D. Atlas (ed.), American Meteorological Society Boston, 619-647 (1990).

No abstract.

NS-010

CARACENA, F. Low pass filter response characteristics of analytic approximations by weighted sums for single pass, multipass, and optimal schemes. Preprints, 11th Conference on Probability and Statistics in Atmospheric Sciences, Monterey, CA, October 2-6, 1989. American Meteorological Society, Boston, 20-25 (1989).

No abstract.

NS-011

CARACENA, F., and A. MARROQUIN. The use of a gridless analysis scheme in complex, diagnostic calculations. Extended Abstracts, WMO International Symposium on Assimilation of Observations in Meteorology and Oceanography, Clermont-Ferrand, France, July 9-13, 1990. World Meteorological Organization, Geneva, Switzerland, 566-571 (1990).

No abstract.

NS-012

CARBONE, R., B. Foote, M. Moncrief, T. Gal-Chen, W. Cotton, M. Hjelmfelt, F. Roux, G. Heymsfield, and E. BRANDES. Convective dynamics: Panel report. In Radar in Meteorology: Battan Memorial and 40th Anniversary Radar Meteorology Conference, D. Atlas (ed.). American Meteorological Society, Boston, 391-400 (1990).

No abstract.

NS-013

Carpenter, R.L., K.K. Droegemeier, P.R. Woodward, and C.E. HANE. Application of the piecewise parabolic method to meteorological modeling. Monthly Weather Review 118: 586-612 (1990).

The Piecewise Parabolic Method (PPM), a numerical technique developed in astrophysics for modeling fluid flows with strong shocks and discontinuities, is adapted for treating sharp gradients in small-scale meteorological flows. PPM differs substantially from conventional gridpoint techniques in three ways. First, PPM is a finite volume scheme, and thus represents physical variables as averages over a grid zone rather than single values at discrete points. Second, a unique, monotonic parabola is fit to the zone average of each dependent variable using information from neighboring zone averages. As shown in a series of one- and two-dimensional linear advection experiments, the use of parabolas provides for extremely accurate advection, particularly of sharp gradients. Furthermore, the monotonicity constraint renders PPM's solutions free from Gibbs oscillations. PPM's third attribute is that each zone boundary is treated as a discontinuity. Using the method of characteristics the nonlinear flux of quantities between zones is obtained by solving a Riemann problem at each zone boundary in alternating one-dimensional sweeps through the grid. This methodology provides a highly accurate, physically based solution both in the vicinity of sharp gradients and in regions where the flow is smooth. The ability of PPM to accurately depict the evolution of sharp gradients in small-scale, nonlinear flows is examined by simulating a buoyant thermal and a density current in two dimensions. Comparisons made against gridpoint cloud models reveal that PPM provides superior solutions at equivalent spatial resolution, particularly with regard to resolving shear lines that subsequently become unstable. The PPM model has excellent mass and energy conservation properties, and exhibits virtually no numerical dissipation of resolvable modes. Although PPM is not yet as economical as a conventional gridpoint model, we anticipate that its efficiency can be greatly improved by modifying the treatment of acoustic modes.

NS-014

Conway, J.W., and D.S. ZRNIC'. The differential reflectivity column: Its importance as embryo source and hailgrowth regions. Preprints, 1990 Conference on Cloud Physics, San Francisco, CA, July 23-27, 1990, American Meteorological Society, Boston, 432-436 (1990).

On 13 June 1984 a series of severe hailstorms devastated the Denver, CO, metropolitan area. During this time the NCAR CP2 radar collected multiparameter data including Zdr and Ldr measurements. Discussed in this paper is a region of high Zdr above the freezing level corresponding to what is believed to be drops advected within the main updraft region. Also examined is the role of this high Zdr region in both frozen drop hailstone embryo production and as a wet growth environment. It is shown through dual-Doppler and trajectory analysis that this column is important in both aspects.

NS-015

DOSWELL, C. A. III. Comments on the need for augmentation in automated surface observation. National Weather Digest 15: (1990).

No abstract.

NS-016

DOSWELL, C. A. III. Comments on vertical motion evaluation of a Colorado snowstorm from a synoptician's perspective. Weather and Forecasting 4: 568-570 (1989).

No abstract.

NS-017

DOSWELL, C. A. III. On the use of hodographs: Vertical wind profile information applied to forecasting severe thunderstorms (2nd ed.). NOAA/NWS/SRH, Scientific Services Division, Fort Worth, Texas, and NOAA/ERL, National Severe Storms Laboratory, Norman, Oklahoma, 37 pp. (1990).

No abstract.

NS-018

DOUGLAS, M.W., M.A. SHAPIRO, L.S. FEDOR, and L. Saukkonen. Research aircraft observations of a polar low at the East-Greenland ice-edge. Extended Abstracts, 4th Conference on Mesoscale Processes, Boulder, CO, June 25-29, 1990. American Meteorological Society, Boston, 22-23 (1990).

No abstract.

NS-019

DOVIAK, R.J., K.W. Thomas, and D.R. Christie. The wavefront shape, position, and evolution of a great solitary wave of translation. IEEE Transactions on Geoscience and Remote Sensing 27: 658-665 (1989).

Doppler radar mapped the evolution of a pair of atmospheric solitary waves emanating from a thunderstorm complex. The 100-km-long curved wavefront and position of these few-kilometer-wide waves are hypothesized to be a result of an amplitude-dependent wave speed. The observed unfolding is compared with a solution of the nonlinear integro-differentiual equation governing the evolution of finite amplitude disturbances in stratified media.

NS-020

EILTS, M.D., and S.D. Smith. Efficient dealiasing of Doppler velocities using local environment constraints. Journal Atmospheric Technology 7: 118-128 (1990).

A Doppler velocity dealiasing algorithm is described that processes one radial at a time by comparing that radial with a previous radial. This technique has worked reliably on numerous Doppler radar data sets for clear air, thunderstorm, and severe thunderstorm situations. It was also tested on four volume scans from severe weather environments with difficult aliasing problems to determine statistically how well the algorithm performs in a worst case environment. Of some 1.2 million velocities in these severe storms, 0.2% were improperly dealiased, and 93% of those were above 13 km height in the storm-top divergent region where shears were extreme. Every tornado, mesocyclone, gust front, microburst, and storm-top divergent signature was preserved, and could be readily discerned by human analysts. No adverse impact was observed on the signatures, and automated signature detection algorithms would therefore be freed from contamination by velocity aliasing. The velocity dealiasing algorithm described is adaptive and therefore efficient because simple checks are made initially, and progressively more sophisticated and time-consuming checks are used only if they are needed.

NS-021

FORSYTH, D.E., D.W. BURGESS, C.A. DOSWELL III, M.H. JAIN, L.E. Mooney, R.M. RABIN, and W.D. RUST. DOPLIGHT '87 Project Summary. NOAA TM ERL NSSL-101 (PB90-253584), 83 pp. (1990).

No abstract.

NS-022

Fulton, R., D.S. ZRNIC, and R.J. DOVIAK. Initiation of a solitary wave family in the demise of a nocturnal thunderstorm density current. Journal of the Atmospheric Sciences 47 (3):319-337 (1990).

This paper describes the characteristics and evolving nature of a vigorous thunderstorm density current very early in the morning of 9 May 1981 in Oklahoma. Because the ambient lower atmosphere was stratified, interesting interactions between the outflow current and the ambient environment resulted. The leading portion of the current was modulated by at least three gravity wavelike perturbations of horizontal spacing 12 km which initially coexisted with it. However, as the current evolved, it initiated an undular borelike disturbance which propagated ahead into the stable boundary layer, carrying cold outflow air in large amplitude rolls. Eventually the wave family left the decelerating outflow in its wake. This borelike disturbance resembles the Australian "morning glory" phenomenon and appears to represent an early stage in the development of a solitary wave family. The observations resemble other reported morning glories and solitary waves as well their laboratory and numerically simulated counterparts. Comparisons are discussed. This case study is unique not only because it combines Doppler radar, tall tower, and surface mesonet observations, but especially because the period of observation captures the disturbance in its formative stage when it is still very near the density current.

NS-023

HANE, C.E. Retrieval of dynamic variables in convective cloud systems observed by Doppler radar. Atmospheric Research 25: 217-234 (1990).

Multiple Doppler radar data of high quality can be analyzed to produce the three wind velocity components, subject to the mass continuity constraint, within precipitating convective clouds. Further, the wind components can be used in concert with the governing momentum equations to retrieve pressure and buoyancy variables within the same precipitation volume. Errors in velocity components produce errors in the derived pressure and buoyancy fields; however, the quality of the retrieved pressure gradients (and therefore velocity analysis) can be checked by measuring how well those gradients match the pressure gradients found within the individual horizontal momentum equations. Examples of retrieved fields are shown from isolated severe thunderstorms, including a tornadic storm that occurred in Oklahoma and a hailstorm in eastern Montana, and from a squall line containing both convective and stratiform precipitation. In both the isolated and squall line convection the pressure distribution near strong updrafts conforms to that predicted by linear theory. The results from the hailstorm calculations are reported in some detail in order to illustrate the pressure and buoyancy structure in various parts of the storm and to relate the pressure structure to storm propagation. In most observed cases velocity analyses are not available with sufficient frequency to allow calculation of local time changes in the momentum equations, and a steady state must therefore be assumed. To minimize errors in the solutions, calculations should be performed in a reference frame moving with the storm as nearly as possible. Using the hailstorm calculations as an example, a method is illustrated for finding this optimal reference frame utilizing the governing momentum equations.

NS-024

HOLLE, R.L., R.E. LOPEZ, and A.I. WATSON. Cloud-to-ground lightning detection using direction-finder networks: Recent advances and applications. Bulletin of the World Meteorological Organization 39:177-179 (1990).

No abstract.

NS-025

Houze, R.A., B.F. SMULL, and P. DODGE. Mesoscale organization of springtime rainstorms in Oklahoma. Monthly Weather Review 118:613-654 (1990).

Radar reflectivity and raingage data obtained during six springtimes indicate the types of mesoscale organization that occur in association with major rain events in Oklahoma (at least 25 mm of rain in 24 h over an area exceeding 12 500 km^2). In these storms the primary rain area is found to be a contiguous region of precipitation 10s to 100s of km in scale that consists partly of deep convection and partly of stratiform rain. The patterns of rain formed by the convective and stratiform areas comprise a continuous spectrum of mesoscale structures. About two-thirds of the cases examined exhibited variations on the type of organization in which convective cells arranged in a moving line are followed by a region of stratiform rain. Storm organization was graded according to the degree to which it matched an idealized model of this "leading-line/trailing-stratiform" structure. The precipitation pattern was further graded according to whether its structure was relatively symmetric with respect to an axis normal to and passing through the midpoint of the line, or asymmetric, in which case the storm was biased toward having stronger, more discrete convective structure at the upwind (south or southwestern) end of the line and/or the most extensive stratiform precipitation behind the downwind (north to northeastern) end of the line. About one-third of the cases examined displayed much more chaotic, unclassifiable arrangements of convective and stratiform areas. Among the cases with leading-line/trailing-stratiform structure, severe weather was most frequent in systems with (i) a strong degree of leading-line/trailing-stratiform structure, in which a solid, relatively uniform, arc-shaped line had stratiform rain centered symmetrically behind it, and (ii) a weaker degree of leading-line/trailing-stratiform structure in which a southwest-northeast line was biased toward having narrow, intensely convective, irregularly spaced cell structure at its southwestern (upwind) end and stratiform rain confined to the region behind the broader northeastern (downwind) portion of the line. Although all mesoscale organization types were characterized by all types of severe weather, the type (ii) cases were the most prolific category in terms of tornado and hail production, while type (i) cases were prone to be associated with flooding. The chaotic, unclassifiable cases, which exhibited no line organization, had just as much severe weather as the cases with line organization, but were more likely to produce hail and somewhat less likely to produce tornadoes and flooding than the systems with line structure. Major rain events occurred whenever a mesoscale convective complex (MCC) was passing over the study area, unless the MCC was dissipating or merely skirting the area. However, 75% of the major rain events occurred under cloud shields that failed to meet the MCC criteria explicitly although they often resembled MCCs qualitatively. No particular type of mesoscale radar-echo organization was favored when cloud shields meeting the MCC criteria were observed. A slight preference for the more chaotic type of organization was suggested; however, the data sample is not large enough for this finding to be regarded as conclusive. Mean soundings and hodographs generally show no sign of a low-level jet in environments associated with chaotically arranged rain areas that lacked any line structure. On the other hand, a low-level jet and resulting curved hodograph were typically associated with cases in which line organization was evident. The wind shear in the low-to-mid troposphere, the bulk Richardson number and other familiar parameters characterizing squall line environments are consistent with results from recent modeling studies. When leading-line/trailing-stratiform structure was present, the cross-line shear in the environment was of a magnitude associated with model simulations in which a rearward sloping updraft circulation favorable to trailing-stratiform anvil formation quickly develops. The along-line component of shear was greater when the

squall system structure was of the asymmetric type and the degree of leading-line/trailing-stratiform structure was not as strong, i.e. in those mesoscale systems favoring tornado occurrence.

NS-026

Johnson, R., S. Chen, G. Stumpf, and D. BARTELS. The vertical structure of a midtropospheric vortex within the stratiform region of a mesoscale convective system. Extended Abstracts, 4th Conference on Mesoscale Processes, Boulder, CO, June 25-29, 1990. American Meteorological Society, Boston, 216-217 (1990).

No abstract.

NS-027

JORGENSEN, D.P., and R. Meneghini. Airborne/spaceborne radar. Panel report. In Radar in Meteorology: Battan Memorial and 40th Anniversary Radar Meteorology Conference, D. Atlas (ed.). American Meteorological Society, Boston, 315-322 (1989).

No abstract.

NS-028

Lee, J.T., and K. Thomas. Turbulence spectral widths view angle independence as observed by Doppler radar. Final Report DOT/FAA/SA-89/2 to Federal Aviation Administration. Available through National Technical Information Service, Springfield, VA 22161, 47pp (1990).

As air traffic density increases, effective use of airspace must include consideration of weather. Accurate identification of turbulent volumes is of paramount importance to flight safety. The advent of Doppler radar has made it possible to observe wind motion in convective clouds. Over a number of years, research has lead to the spectral width (standard deviation) of the Doppler velocity measurements as an indicator of turbulence. In this paper we address the hypothesis that turbulence is essentially isotropic in convective systems, and therefore, observations of turbulence are independent of viewing angle. Radar observations made during the months of April, May, and June in 1980-1985 were scanned to locate storms amenable to analysis. A number of cases are presented in which a dual-Doppler network provided the essential data. Each case is in a different quadrant with respect to the Norman Doppler. Forty-four horizontal planes were studied from six different storms. The results of four of these storms are presented. Maximum reflectivity of these storms range from 51 to 58 dBZ. Altitudes included in this study range from near surface to 7 km. At these altitudes, the maximum spectral width was $12ms^{-1}$. For these cases, involving nearly 30,000 data points, 70% of the spectral width observations from CIM and NRO were within $1ms^{-1}$, and 88% had a difference of $2\ ms^{-1}$ or less. These results indicate that the use of Doppler radar to detect turbulent regions has a high probability of success, and the turbulent regions can be detected independent of the direction from which they are viewed.

NS-029

LeMone, M.A., and D.P. JORGENSEN. Momentum generation and redistribution in a TAMEX convective band. Preprints, Workshop on TAMEX Scientific Results, Boulder, CO, September 24-26, 1990. National Center for Atmospheric Research, Boulder, 42-47 (1990).

No abstract.

NS-030

LeMone, M.A., J.C. Fankhauser, and T. MATEJKA. Momentum generation and redistribution in convective bands: What have we learned? Extended Abstracts, 4th Conference on Mesoscale Processes, Boulder, CO, June 25-29, 1989. American Meteorological Society, Boston, 198-199 (1990).

No abstract.

NS-031

LEWIS, J., C. Hayden, and J. Derber. A method for combining radiances and wind shear to define the temperature structure of the atmosphere. Bulletin of the American Meteorological Society 117:1193-1207 (1989).

The retrieval of temperature from satellite-observed radiances has traditionally been addressed as a one-dimensional or columnar problem which uses a guess profile of temperature. In this study, the traditional approach is augmented by incorporating observed wind shear as a general thermal wind constraint in the inversion of radiances to make a three-dimensional temperature analysis. The problem is cast as a classical variational problem that minimizes a weighted sum of squares subject to constraint. The constraints are the general thermal wind equation and a set of regression equations expressing the radiances in terms of the temperature profile. The

solution is found by the method of conjugate gradients. Experiments using observed winds with both simulated and observed radiances for the GOES VISSR Atmospheric Sounder (VAS) are described. In both cases, a first guess from a numerical forecast is used. Simulated radiances are used to establish the optimal relative weighting of the wind versus radiance observations and to determine the limits of accuracy on the retrieved temperature under idealized conditions. These relative weights are used in the real data experiments. Experiments are included where weights are varied horizontally and vertically to simulate uneven distribution or confidence in the data. Results indicate that (i) the inclusion of wind shear with simulated radiances reduces the cumulative error variance in the temperature estimate and reduces guess dependence; (ii) horizontal and vertical variations in parameter weighting is viable and well-behaved; and (iii) the algorithm's rate of convergence makes it suitable for small computer applications. Experiments with observed radiances are not as successful. The measured radiances do not improve the forecast. The principal deficiency appears to be that the regression model for expressing the radiances is inadequate to account for the influence of water vapor which affect the VAS measurements or the nonblinearity of radiance with respect to temperature. Extensions to the model as well as application to microwave measurements, which do not suffer these deficiencies, are discussed.

NS-032

MATEJKA, T., and M.A. LeMone. The generation and redistribution of momentum in a squall line. Extended Abstracts, 4th Conference on Mesoscale Processes, Boulder, CO, June 25-29, 1990. American Meteorological Society, Boston, 196-197 (1990).

No abstract.

NS-033

MATEJKA, T., and C.L. ZIEGLER. The effect of hydrometeor evolution on dynamical processes in the stratiform region of a mesoscale convective system. Preprints, 1990 Conference on Cloud Physics, San Francisco, CA, July 23-27, 1990. American Meteorological Society, Boston, 679-682 (1990).

No abstract.

NS-034

MAZUR, V. and B.D. Fisher. Cloud-to-ground strikes to the NASA F-106 airplane. Journal of the Aircraft 27:466-468 (1990).

No abstract.

NS-035

MAZUR, V., B.D. Fisher,and P.W. Brown. Multistroke cloud-to-ground strike to the NASA F-106B airplane. Journal of Geophysical Research 9:5471-5484 (1990).

An analysis of electromagnetic waveform records and video images of a multistroke cloud-to-ground (CG) strike to the NASA F-106B instrumented airplane is presented. The CG flash started as a lightning strike triggered by the airplane and later produced multiple return strokes to the ground (the ground strike network registered 6 return strokes). Although there are some uncertainties in data interpretation resulting from lack of independent measurements with other than the airborne instruments, recoil streamers and eight sequences of dart leaders followed by return strokes (three more than indicated by the ground network) were identified in the airborne data. At least three of the subsequent return strokes were attached to the airplane. The analysis provides evidence that formation of recoil streamers and dart leaders is accompanied by a surge in continuous current. This feature is similar to that observed in the bi-directional leader development during lightning initiation on the airplane.

NS-036

Parsons, D.B., B.F. SMULL, and D.K. Lilly. Mesoscale organization and processes: Panel report. In Radar in Meteorology: Battan Memorial and 40th Anniversary Radar Meteorology Conference, D. Atlas (ed.). American Meteorological Society, Boston, 461-476 (1989).

No abstract.

NS-037

RABIN, R.M.. Capabilities of measuring cloud variability from satellites. Proceedings from the Workshop on Mechanisms for Tropospheric Effects of Solar Variability and the Quasi-Biennial Oscillation. National Center for Atmospheric Research, Boulder, CO., June 20-21, 42-74 (1989).

The capabilities and limitations of satellite measurements of cloud variability are reviewed. Seasonal and regional characteristics of cloudiness are compared from previous studies. Although it is possible to infer certain aspects of cloud cover via reflected solar radiation and upwelling longwave radiation, the vertical distribution of clouds cannot be determined in all conditions. Satellite measurements of reflected short wave and outgoing longwave fluxes are well suited to determine the net heat balance of the earth-atmosphere system. The impact of clouds can be inferred, giving insight into possible feedbacks on atmospheric circulation as a result of changes in the heat balance. Time-series of outgoing longwave radiation (OLR) are presented during the last 11-year solar cycle and are found to be highly correlated with the 10.7 cm solar flux. Possible influence of varying global temperature and cloudiness on the OLR are examined. Interannual changes in global cloudiness have not yet been determined with sufficient accuracy.

NS-038

RABIN, R.M., and R.J. DOVIAK. Meteorological and astronomical influences on radar reflectivity in the convective boundary layer. Journal of Applied Meteorology 28:1226-1235 (1989).

Observations are presented of time-varying radar reflectivity during a partial solar eclipse in Oklahoma. The measurements, from a radar of 10 cm wavelength, were obtained in the clear-air convective boundary layer. The reflectivity changes closely follow the variation in solar radiation associated with the eclipse. Possible mechanisms for the change in reflectivity are reviewed, in particular the effect of surface fluxes of heat and moisture.

NS-039

RABIN, R.M., S.J. Stadler, P. Wetzel, D.J. STENSRUD, and M. Gregory. Observed effects of landscape variability on convective clouds. Bulletin of the American Meteorological Society 71:272-280 (1990).

Visible and infrared satellite images, in combination with detailed landscape information, suggest an appreciable effect of spatial variations in landscape on cumulus cloud formation over relatively flat terrain. These effects are noticeable when forcing from the atmosphere is weak, for instance when fronts or other disturbances are absent. A case is presented in which clouds are observed to form first over a mesoscale-size area (100x300 km) of harvested wheat in Oklahoma where the ground temperature is warmer than over adjoining areas dominated by growing vegetation. In addition, clouds are suppressed over relatively long bands downwind of small man-made lakes and areas characterized by heavy tree cover. The observed variability of cloud relative to landscape type is compared with that simulated with a one-dimensional boundary layer model. Clouds form earliest over regions characterized by high sensible heat flux, and are suppressed over regions characterized by high latent heat flux during relatively dry atmospheric conditions. This observation has significance to understanding the feedback mechanisms of land modification on climate, as well as to relatively short-range weather forecasting.

NS-040

Ray, P.S., C.L. ZIEGLER, and S.L. Lang. Retrieval of microphysical variables in New Mexican mountain thunderstorms from Doppler radar data. Preprints, Conference on Cloud Physics, San Francisco, CA, July 23-27, 1990, American Meteorological Society, Boston, 437-442 (1990).

No abstract.

NS-041

RUST, W.D., R.P. DAVIES-JONES, D.W. BURGESS, R.A. MADDOX, L.C. SHOWELL, T.C. Marshall, and D.K. Lauritsen. Testing a mobile version of a cross-chain atmospheric sounding system (M-CLASS). Bulletin of the American Meteorological Society 71: 173-180 (1990).

We have tested the NCAR Cross-Chain LORAN Atmospheric Sounding System (CLASS) in a fully mobile configuration, which we call M-CLASS. The sondes use LORAN-C navigation signals to allow calculation of balloon position and horizontal winds. In non-stormy environments, thermodynamics and wind data were almost always of high quality. Besides providing special soundings for operational forecasts and research programs, a major feature of mobile ballooning with M-CLASS is the ability to obtain additional data by flying other instruments on the balloons. We flew an electric field meter, along with a sonde, into storms on 8 of the initial 47 test flights in the spring of 1987. In storms, pressure, temperature, humidity, and wind data were of good quality about 80%, 75%, 60% and 40% of the time, respectively. In a flight into a mesocyclone, we measured electric fields as high as - 135 kV/m (at 10 km MSL) in a region of negative charge. The electric field data from several storms allow a quantitative assessment of conditions that accompany loss of LORAN data. We provided our early-afternoon M-CLASS test soundings to the National Weather Service Office in Norman, Oklahoma, in near real-time via amateur packet radio and also to the National Severe Storms Forecast Center. These soundings illustrate the potential for improving operational forecasts. Other test flights showed that M-CLASS data can provide high-resolution information on evolution of the Great Plains low-level jet stream. Our intercept of Hurricane Gilbert provided M-CLASS sounding in the right quadrant of the storm. We observed substantial wind shear in the lowest levels of the soundings around the time

tornadoes were reported in south Texas. This intercept demonstrated the feasibility of taking M-CLASS data during the landfall phase of hurricanes and tropical storms.

NS-042

Rutledge, S.A., C. Lu, and D.R. MacGORMAN. Positive cloud-to-ground lightning in mesoscale convective systems. Journal of the Atmospheric Sciences 47: 2085-2100 (1990).

We have examined the characteristics of positive cloud-to-ground lightning flashes in Mesoscale Convective Systems observed during the Oklahoma-Kansas PRE-STORM project in 1985. Lightning frequencies and patterns of ground strike locations are related to observed storm precipitation structures, with emphasis placed on relating observed lightning patterns to the stratiform precipitation regions. Positive ground flashes are categorized in relation to their position relative to storm radar echo patterns, and frequency of occurrence relative to storm lifecycles. Observations presented indicate that many of the positive flashes are likely produced by the advection of positive charge from the upper levels of the convective portions of the storm. We suggest that an additional class of positive ground flashes are associated with the generation of charge by stratiform precipitation processes, specifically related to ice-ice interactions in regions of low supercooled liquid water contents. A simple one-dimensional model is developed and used to show that stratiform microphysical processes are capable of producing charge densitities of 2-4 C km^{-3}. The charge structure inferred from the model is an inverted dipole with positive charge being situated below negative charge. The model results are contrasted to charge structures inferred from observational studies, one of which suggests the presence of an inverted polarity dipole.

NS-043

SMULL, B.F., and D.P. JORGENSEN. Pressure and buoyancy perturbations near an intense wake low in a midlatitude mesoscale convective system. Extended Abstracts, 4th Conference on Mesoscale Processes, Boulder, CO, June 25-29, 1990. American Meteorological Society, Boston, 214-215 (1990).

No abstract.

NS-044

Stumpf, G.J. The gust front detection algorithm for the terminal Doppler weather radar: Impact of NEXRAD scan strategies; detecting non-gust front phenomena. Preprints, 10th Annual International Geosciences & Remote Sensing Symposium, College Park, MD, May 20-24, 1990, 743-746 (1990).

No abstract.

NS-045

SZOKE, E.J., and J.A. AUGUSTINE. An examination of the mean flow and thermodynamic characteristics of a mesoscale flow feature: The Denver cyclone. Extended Abstracts, 4th Conference on Mesoscale Processes, Boulder, CO, June 25- 29, 1990. American Meteorological Society, Boston, J17-J18 (1990).

No abstract.

NS-046

TOLLERUD, E., J. BROWN, and D.L. BARTELS. Structure of an MCS-induced mesoscale vortex as revealed by VHF profiler, Doppler radar, and satellite observations. Preprints, 12th Conference on Weather Analysis and Forecasting, Monterey, CA, October 2-6, 1989. American Meteorological Society, Boston, 81-86 (1989).

No abstract.

NS-047

Williams, E., V. MAZUR, and S. Geotis. Lighting investigation with radar. In Radar in Meteorology: Battan Memorial and 40th Anniversary Radar Meteorology Conference, D. Atlas (ed.) American Meteorological Society, Boston, 143-150 (1990).

No abstract.

NS-048

ZRNIC, D.S. Signal processing: Panel report. In Radar in Meteorology: Battan Memorial and 40th Anniversary Radar Meteorology Conference, D. Atlas (ed.). American Meteorological Society, Boston, 230-234 (1990).

No abstract.

NS-049

ZRNIC, D.S. and Z. Banjanin. Ground clutter filters for staggered pulse trains. Final Report DOT/FAA/SA-89/2, Federal Aviation Administration, Washington, DC, 57 pp. (1989).

Several methods for canceling ground clutter on Doppler weather radars that operate with staggered PRT's are investigated. The scheme is developed that consists of two filters that operate sequentially, so that the overall filter is time-varying, with periodically changing coefficients. This filter is analyzed theoretically and through simulations for a stagger ratio of 3/2, which extends the unambiguous velocity interval (at a wavelength of 5 cm) to 50 m s^{-1}. The amplitude characteristic of the filter over this interval is very good, but phase characteristic, which is nonlinear in about 40% of the interval, requires that a special decision logic be used for velocity estimation. At high signal-to-noise ratio (> 20 dB), mean velocities obtained from the output meet terminal Doppler weather radar specifications.

PACIFIC MARINE ENVIRONMENTAL LABORATORY

PM-001

AAGAARD, K., and E.C. Carmack. The role of sea ice and other fresh water in the arctic circulation. Journal of Geophysical Research 94(C10):14,485–14,498 (1989).

Salinity stratification is critical to the vertical circulation of the high-latitude ocean. We here examine the control of the vertical circulation in the northern seas, and the potential for altering it, by considering the budgets and storage of fresh water in the Arctic Ocean and in the convective regions to the south. We find that the present-day Greenland and Iceland seas, and probably also the Labrador Sea, are rather delicately poised with respect to their ability to sustain convection. Small variations in the fresh water supplied to the convective gyres from the Arctic Ocean via the East Greenland Current can alter or stop the convection in what may be a modern analog to the halocline catastrophes proposed for the distant past. The North Atlantic salinity anomaly of the 1960s and 1970s is a recent example; it must have had its origin in an increased fresh water discharge from the Arctic Ocean. Similarly, the freshening and cooling of the deep North Atlantic in recent years is a likely manifestation of the increased transfer of fresh water from the Arctic Ocean into the convective gyres. Finally, we note that because of the temperature dependence of compressibility, a slight salinity stratification in the convective gyres is required to efficiently ventilate the deep ocean.

PM-002

AAGAARD, K., C.H. PEASE, A.T. ROACH, and S.A. SALO. Beaufort Sea mesoscale circulation study—Final Report. NOAA TM ERL PMEL-90 (NTIS PB90-158775), 114 pp. (1989).

The Beaufort Sea Mesoscale Project was undertaken to provide a quantitative understanding of the circulation over the Beaufort Sea shelf and of its atmospheric and oceanic forcing. Major emphasis has been placed on providing extensive synoptic oceanographic and meteorological coverage of the Alaskan Beaufort Sea during 1986–88. In addition, supplementary measurements have been made in the southern upstream waters of Bering Strait and the Chukchi Sea. The work has resulted in an unprecedented regional data set for both the ocean and the atmosphere. The principal conclusions are as follows: 1) Below the upper 40–50 m of the ocean, the major circulation feature of the outer shelf and slope is the Beaufort Undercurrent, a strong flow which is directed eastward in the mean, but which is subject to frequent reversals toward the west. The reversals are normally associated with upwelling onto the outer shelf. The undercurrent is very likely part of a basin-scale circulation within the Arctic Ocean. 2) While we find statistically significant wind influence on the subsurface flow in the southern Beaufort Sea, it is generally of secondary importance, accounting for less than 25% of the flow variance below 60 m. An important implication is that at least below the mixed layer, the circulation on the relatively narrow Beaufort shelf is primarily forced by the ocean rather than by the local wind. This oceanic forcing includes shelf waves and eddies. Therefore, to the extent that a localized problem or process study requires consideration of the shelf circulation, such as would be the case for oil-spill trajectory modeling, a larger-scale framework must be provided, within which the more local problem may be nested. 3) There were large changes in wind variance with season, with the largest variances occurring in the late summer/early autumn and again in January because of blocking ridges in the North Pacific shifting the storm track westward over the west coast of Alaska and across the North Slope. 4) Despite the seasonally varying wind field, as well as the large seasonal differences in the upper-ocean temperature and salinity fields, we find no evidence for a seasonal variability in the subsurface circulation in the Beaufort Sea. This situation contrasts with that in Bering Strait and probably in the Chukchi Sea, where a seasonal cycle in the transport is apparent. Therefore, while the northward flow of water from the Pacific is of major significance to the structure and chemistry of the upper ocean in the Arctic (including the Beaufort Sea), as well as its ice cover and biota, the dynamic significance of that flow to the Beaufort Sea appears small. 5) In contrast to the lack of a seasonal oceanographic signal at depth, the interannual variability in the flow characteristics can be considerable. For example, during the period fall 1986-spring 1987, the Beaufort Undercurrent appears to have been deeper by 30–40 m compared with both earlier and ensuing measurements. The consequences of such anomalies for the upper-ocean velocity structure and transport are likely significant. 6) During much of the experiment, the meteorological conditions were milder than normal, consistent with less coastal ice in the summer and autumn, the passage of more storms up the west coast of Alaska and across the North Slope, and generally higher air temperatures along the North Slope. These climatological near-minimum ice years were followed in 1988 by the heaviest summer ice along the Chukchi coast since 1975. 7) The atmospheric sea-level pressure field was well represented by the METLIB products from the FNOC surface analysis if the 12-hour lag of the FNOC pressures was taken into account. However, the FNOC surface air temperature field does not accurately represent either the land-based stations or the drifting ice buoys. The errors in the FNOC temperature field showed a systematic over-prediction during winter and spring of 10–20°C, leading to an annual over-prediction of air temperature by 3–13°C at all sites. Gradient winds from FNOC are therefore well suited for modeling purposes if they are calculated from the time-shifted surface analysis, but the FNOC surface temperature analysis should not be used for any model calculations, except perhaps as an upper boundary condition for a rather complete planetary boundary layer model.

PM-003

Appelgate, T.B., Jr. Volcanic and structural morphology of the south flank of Axial Volcano, Juan de Fuca Ridge: Results from a Sea MARC I side scan sonar survey. Journal of Geophysical Research 95(B8):12,765–12,783 (1990).

A 1500 km^2 Sea MARC I side scan sonar survey south of Axial Volcano investigated the geological structure and constitution of the

South Axial Rift Zone (SARZ) and the northern 30 km of the Vance spreading segment. Relative age assignments based on structural relationships indicate that recent volcanism on the southern flank of Axial Volcano has been restricted to the SARZ. The surficial volcanic morphology of the SARZ changes downrift, from linear volcanic ridges (north) to small (1-km diameter) cratered cones (south), perhaps indicating a variation in eruptive vent geometry from fissures to point sources downrift. Recent lavas on the northern and central SARZ erupted along preexisting faults in the underlying crust. By acting as pathways for SARZ magmas, these faults may have controlled the orientation of SARZ volcanic ridges and perhaps the orientation of the entire SARZ edifice. The Vance spreading segment terminates at 45°40′N and is not linked with a transform fault. The axis of spreading between 45°40′N and 46°00′N is offset west of the Vance segment and is constrained to lie between 129°54′W and 130°06′W. A discrete, structurally defined spreading axis, however, is not evident over the southern flank of Axial Volcano. The divergent plate boundary may now underlie the SARZ massif, although South Helium Basin (an embayment in the southeast flank of Axial Volcano) has undergone, and may continue to accommodate, crustal extension. A 48 km^2 lava field discovered east of the SARZ is composed of lavas that are inferred to have erupted from the SARZ. These lavas can be traced eastward from the SARZ into the axial valley of the northern Vance segment and partially fill the valley with lavas up to 60 m thick. The eruption of these lavas, which occupy an estimated volume of 1.8 km^3, may have contributed to the formation of Axial Volcano's summit caldera.

PM-004

BAKER, E.T. Hydrothermal plume prospecting: hydrographic and geochemical techniques. In Gorda Ridge: A Seafloor Spreading Center in the United States Exclusive Economic Zone, G.R. McMurray (ed.). Springer-Verlag, New York, 155–167 (1990).

Hydrothermal plumes, formed by the mixing of hot vent fluids and ambient seawater, can be used to locate, characterize, and quantify sources of seafloor hydrothermal emissions. Vent fluids typically undergo a 10^6-fold dilution as they rise several hundred meters above the sea floor and form neutrally buoyant plumes with heat and chemical anomalies that stretch tens to thousands of kilometers downcurrent of their source. Real-time mapping of these plumes by towing sensitive hydrographic and optical sensors from a surface ship can efficiently locate the plume source, guide discrete chemical sampling of the diluted hydrothermal fluids, and estimate the heat and mass flux of individual vent fields. This paper uses case histories of investigations along the Juan de Fuca and Gorda Ridges to describe strategies for mapping and characterizing hydrothermal plumes at spatial scales ranging from hundreds of meters to hundreds of kilometers.

PM-005

BAKER, E.T., and J.E. Lupton. Changes in submarine hydrothermal ^{3}He/heat ratios as an indicator of magmatic/tectonic activity. Nature 346:556–558 (1990).

An important question in submarine hydrothermal research concerns the connection between hydrothermal discharge from a spreading centre and variations in local magmatic and tectonic activity. Because it is likely that tectonic stretching and concomitant shallow magmatic activity triggered the cataclysmic venting that created the Juan de Fuca Ridge "megaplumes," we have for three years monitored the ^{3}He concentration and temperature anomaly of the underlying steady-state plume at the site of the original megaplume. We report here that the apparent ^{3}He/heat ratio in the steady-state plume has progressively decreased from 4.4 to 2.4 to 1.3×10^{-12} cm^3 STP cal^{-1}, changing from a uniquely high ratio to one characteristic of established vent fields on other ridge segments. We propose that the initially high ^{3}He/heat ratio, sampled within days of the megaplume eruption, resulted from magma degassing into a hydrothermal circulation system of high permeability and short fluid residence time. Thus, high ^{3}He/heat ratios may indicate venting created or profoundly perturbed by a magmatic-tectonic event, and lower ratios may typify systems at equilibrium.

PM-006

BAKER, E.T., R.E. McDuff, and G.J. MASSOTH. Hydrothermal venting from the summit of a ridge axis seamount: Axial Volcano, Juan de Fuca Ridge. Journal of Geophysical Research 95(B8):12,843–12,854 (1990).

We have mapped the distribution and intensity of submarine hydrothermal emissions from the summit calders of Axial Volcano by means of hydrographic and chemical sampling of the water column during annual cruises in four consecutive years (1985–1988). These investigations were undertaken to ascertain the strength of hydrothermal venting relative to other vent fields on the Juan de Fuca Ridge and to gauge the importance of Axial Volcano as a source of hydrothermal emissions to the northeast Pacific Ocean. Measurable temperature anomalies are mostly restricted to a 200-m-thick water column within the caldera, where they range from a background level of ~0.01°C to local maxima of 0.02–0.1°C above known high-temperature vent fields. The temperature anomaly plume is significantly smaller in both extent and intensity than plumes emitted by vent fields on other segments of the Juan de Fuca Ridge. A maximum estimate of the total heat flux from the summit, based on the total excess heat and advective velocity of the plume, is 8×10^8 W. Hydrothermal venting seems surprisingly small for an edifice that testifies to a long-term oversupply of magma at a single axial location. We speculate that additional heat may be lost from Axial Volcano by diffuse percolation of seawater over broad areas of its flanks and by magma eruption and venting along flank rift zones.

PM-007

Bane, J.M., C.D. Winant, and J.E. OVERLAND. Planning for coastal air-sea interaction studies in CoPO. Bulletin of the American Meteorological Society 71(4):514–519 (1990).

A number of observational programs have been carried out on the United States continental shelf to describe coastal-ocean circulation with emphasis on mesoscale processes. In several of these studies the atmosphere was found to play a central role in determining the coastal circulation through either local or remote forcing. Because of these results, the Coastal Physical Oceanography (CoPO) planning effort has designated three coastal air-sea interaction areas to focus on in a national program to study the physical processes on the continental shelf. These areas are shelf frontogenesis, interaction of stable layers with topography, and forcing by severe storms. The long-term objective of the air-sea interaction component of CoPO is to better understand the structure, dynamics, and evolution of the various mesoscale and synoptic-scale processes that significantly affect coastal/shelf circulation through air-sea interactions. Within this body of knowledge will be an improved quantification of the air-sea exchanges of dynamically important quantities set in the framework of mesoscale and synoptic-scale processes.

PM-008

BATES, T.S., J.E. JOHNSON, P.K. Quinn, P.D. GOLDAN, W.C. KUSTER, D.C. Covert, and C.J. Hahn. The biogeochemical sulfur cycle in the marine boundary layer over the northeast Pacific Ocean. Journal of Atmospheric Chemistry 10(1):59–81 (1990).

The major components of the marine boundary layer biogeochemical sulfur cycle were measured simultaneously onshore and off the coast of Washington State, U.S.A. during May 1987. Seawater dimethylsulfide (DMS) concentrations on the continental shelf were strongly influenced by coastal upwelling. Concentrations further offshore were typical of summer values (2.2 nmol/L) at this latitude. Although seawater DMS concentrations were high on the biologically productive continental shelf (2–12 nmol/L), this region had no measurable effect on atmospheric DMS concentrations. Atmospheric DMS concentrations (0.1–12 nmol/m^3), however, were extremely dependent upon wind speed and boundary layer height. Although there appeared to be an appreciable input of non-sea-salt sulfate to the marine boundary layer from the free troposphere, the local flux of DMS from the ocean to the atmosphere was sufficient to balance the remainder of the sulfur budget.

PM-009

Bender, M.L., and M.J. MCPHADEN. Anomalous nutrient distribution in the equatorial Pacific in April 1988: evidence for rapid biological uptake. Deep-Sea Research 37(7):1075–1084 (1990).

Nutrients in the central equatorial Pacific are normally enriched at the Equator, with concentrations gradually falling to the north and south. This pattern reflects input by equatorial upwelling, with slow removal as waters flow poleward. In April 1988, we observed *minima* in SiO_2 and $NO_3^- + NO_2^-$ concentrations near the Equator. [SiO_2] in particular dropped to minima at 2.5°N and 1–2.5°S, rose to maxima at 3°N and 3–6°S, then fell off in the normal pattern. Such minima are unusual features not clearly evident in data from other equatorial Pacific transects. A period of anomalous hydrographic conditions preceded the time of our chemical observations. Between February 1988 and April 1988, the anomalously warm conditions which characterized the equatorial Pacific during the 1986–1987 El Niño/Southern Oscillation event ended, and the thermocline shoaled sharply. We speculate that the anomalous nutrient distributions we observed in April are related to the regional hydrography of the preceding months. Physical forcing may have triggered rapid biological SiO_2 and NO_3^- removal, producing the anomalous nutrient distribution we observed.

PM-010

BERNARD, E.N., R.R. Behn, G.T. Hebenstreit, F.I. GONZALEZ, P. Krumpe, J.F. Lander, E. Lorca, P.M. McManamon, and H.B. MILBURN. On mitigating rapid onset natural disasters: Project THRUST (Tsunami Hazards Reduction Utilizing Systems Technology). Proceedings of Workshop XLVI, The 7th U.S.-Japan Seminar on Earthquake Prediction, Menlo Park, CA, 12–15 September 1988. USGS Open-File Report 90-98, 125–130 (1990).

Rapid onset natural hazards have claimed more than 2.8 million lives worldwide in the past 20 years. This category includes such events as earthquakes, landslides, hurricanes, tornados, floods, volcanic eruptions, wildfires, and tsunamis. Effective hazard mitigation is particularly difficult in such cases, since the time available to issue warnings can be very short or even nonexistent. This paper presents the concept of a local warning system that exploits and integrates the existing technologies of risk evaluation, environmental measurement, and telecommunications. We describe Project THRUST, a successful implementation of this general, systematic approach to tsunamis. The general approach includes pre-event emergency planning, real-time hazard assessment, and rapid warning via satellite communication links.

PM-011

BERNARD, E.N., H.B. MILBURN, and T.D. JACKSON. Innovative Oceanography—Pacific Marine Environmental Laboratory's contributions to observing the oceans. Conference Record, The 16th Joint Meeting of the U.S.-Japan Cooperative Program in Natural Resources (UJNR) Marine Facilities Panel, Japan, September 1989, 473–478 (1989).

No abstract.

PM-012

Busalacchi, A.J., M.J. MCPHADEN, J. Picaut, and S.R. Springer. Sensitivity of wind-driven tropical Pacific Ocean simulations on seasonal and interannual time scales. Journal of Marine Systems 1:119–154 (1990).

The purposes of this study are (1) to characterize differences in the time/space structure of various multiyear surface wind products for the tropical Pacific; and (2) to quantify the impact these differences may have on our ability to model oceanic wind-forced variability on seasonal and interannual time scales. Three coincident wind field analyses are used, viz. the Florida State University (FSU) subjective analysis, the University of Hawaii (SAWIN) subjective analysis and the Fleet Numerical Oceanography Center (FNOC) operational analysis. The five years chosen for study, 1979–1983, encompass three years of a fairly regular seasonal cycle leading up to the 1982–1983 El Niño. A linear multi-vertical model model is forced with these analyses; model dynamic height and sea level are then compared with observations based on expendable bathythermograph and island tide gauge data. The mean seasonal cycle prior to El Niño (1979–1981) is considered first, which then serves as a self-consistent basis for analyzing the interannual variability, particularly the significant anomalies about the mean in 1982–1983. The impact of discrepancies in the forcing functions is discussed relative to the dominant seasonal and interannual scales of variability for the wind-driven oceanic response. The analyses of the wind products and model solutions indicate the need for special attention to the wind stress curl fields when evaluating wind products for use in tropical oceanographic applications. On seasonal time scales, critical differences in the wind stress products, of order 0.2–0.4 dyn cm^{-2}, are in wind regimes of surface convergence and significant gradients such as the ITCZ and SPCZ. These uncertainties in the wind fields, or more appropriately the wind stress curl distributions, are manifested in model sea level solutions as 6–12 cm discrepancies near the NECC Trough and east of New Guinea. On average, the seasonal amplitude of the wind-forced sea level response in any one simulation is of the same order as the differences between any two sea level simulations. The interannual variability is dominated by the anomalies associated with the 1982–1983 El Niño. Root mean square differences between the product versus product wind stress anomalies range from 0.1–0.2 dyn cm^{-2} along the major ship tracks and up to 0.5 dyn cm^{-2} away from the shipping lanes. The basin-wide average of the rms differences, approximately 0.25 dyn cm^{-2}, is of similar magnitude to the average wind stress anomaly. Discrepancies in the interannual variability of the wind products lead to large-scale differences in the model sea level anomalies of up to 9–21 cm. The anomalous year to year variability of model sea level is of similar order in each of the simulations. Results for the FSU and SAWIN forced simulations are generally in better agreement with the observations than the FNOC simulation, especially during the 1982–1983 El Niño.

PM-013

Busalacchi, A.J., M.J. MCPHADEN, J. Picaut, and S.R. Springer. Uncertainties in tropical Pacific Ocean simulations: The seasonal and interannual sea level response to three analyses of the surface wind field. Proceedings of the Western Pacific International Meeting and Workshop on TOGA COARE, Nouméa, New Caledonia, May 24–30, 1989. ORSTOM, 367–377 (1989).

The purpose of this study is to characterize differences in time/space structure present among conventional descriptions of the tropical Pacific surface wind field, and in turn, to quantify the impact of these differences on our ability to model the dominant wind-forced variability of the tropical Pacific Ocean on seasonal and interannual time scales. A linear, multiple vertical mode ocean model is used as a transfer function to determine the influence of three distinct surface wind stress products for the period 1979–1983. This five-year period was chosen for study because it encompasses three years of a fairly regular seasonal cycle leading up to the 1982–83 El Niño for which there are several coincident oceanic and surface wind data sets. The three different wind analyses used are the Florida State University subjective analysis, the University of Hawaii subjective analysis, and the Fleet Numerical Oceanography Center objective analysis. We examine first the three mean seasonal cycle solutions prior to El Niño which then serve as self-consistent bases for analyzing the significant anomalies about the mean in 1982–83. The impact of uncertainties in the forcing functions is discussed relative to the dominant seasonal and interannual scales of variability for the wind-driven oceanic response. On seasonal time scales, critical differences in the wind stress products, of order 0.2–0.4 dynes cm^{-2}, were in wind regimes of surface convergence and significant gradients such as the ITCZ and SPCZ. These uncertainties in the wind fields were manifested in model sea level solutions as 6–12 cm discrepancies near the NECC Trough and east of New Guinea. On interannual time scales, the influence of greater sampling along the major ship tracks was evident. Away from the major shipping lanes rms differences in the wind stress anomalies (1979–1983) about the mean seasonal cycle (1979–1981) reached up to 0.5 dynes cm^{-2}. The combined effect of these differences in the wind products resulted in 8–20 cm rms differences in the model sea level simulations. The largest of these discrepancies tended to exist at the terminus of equatorial wave characteristics, e.g. in the east along the equator and in the west off the equator.

PM-014

Butterfield, D.A., G.J. MASSOTH, R.E. McDuff, J.E. Lupton, and M.D. Lilley. Geochemistry of hydrothermal fluids from Axial Seamount Hydrothermal Emissions Study Vent Field, Juan de Fuca Ridge: Subseafloor boiling and subsequent fluid-rock interaction. Journal of Geophysical Research 95(B8):12,895–12,921 (1990).

Hydrothermal fluids collected from the ASHES vent field in 1986, 1987, and 1988 exhibit a very wide range of chemical composition over a small area (~60 m in diameter). Compositions range from a 300°C, gas-enriched (285 mmol/kg CO_2), low-chlorinity (~33% of seawater) fluid to a 328°C, relatively gas-depleted (50 mmol/kg CO_2), high-chlorinity (~116% of seawater) fluid. The entire range of measured compositions at ASHES is best explained by a single hydrothermal fluid undergoing phase separation while rising through the ocean crust, followed by partial segregation of the vapor and brine phases. Other mechanisms proposed to produce chlorinity variations in hydrothermal fluids (precipitation/dissolution of a chloride-bearing mineral or crustal hydration) cannot produce the covariation of chlorinity

and gas content observed at ASHES. There is good agreement of the measured fluid compositions with compositions generated by a simple model of phase separation, in which gases are partitioned according to Henry's law and all salt remains in the liquid phase. Significant enrichments in silica, lithium and boron in the low-chlorinity fluids over levels predicted by the model are attributed to fluid-rock interaction in the upflow zone. Depletions in iron and calcium suggest that these elements have been removed by iron-sulfide and anhydrite precipitation at some time in the history of the low-chlorinity fluids. The distribution of low- and high-chlorinity venting is consistent with mechanisms of phase segregation based on differential buoyancy or relative permeability. The relatively shallow depth of the seafloor (1540 m) and the observed chemistry of ASHES fluids are consistent with phase separation in the sub-critical or near-critical region.

PM-015

CANNON, G.A. Puget Sound circulation: What have observations taught us, and what is still to be ascertained? Oceans '89 Proceedings, Seattle, WA, September 18–21, 1989, Vol. 1: Fisheries, Global Ocean Studies, Marine Policy and Education, Oceanographic Studies. Marine Technology Society, IEEE Publication Number 89CH2780-5, 77–80 (1990).

Understanding circulation and mixing within the Puget Sound estuarine system is important in assessing the fate of natural and man-induced contaminants. The water ultimately either transports contaminants out of the system or redistributes them within it. Research over the past twenty years has focused on directly measuring circulation in sufficient detail to determine the physical processes causing the dominant space and time variations of the flow. This paper summarizes some of our understanding of the estuarine circulation in the central part of the main basin of Puget Sound adjacent to Elliott Bay, some of our uncertainties, and future research needs. This part of Puget Sound has not received sufficient attention.

PM-016

CANNON, G.A. Variations in horizontal density gradient forcing at the mouth of an estuary. In Residual Currents and Long-term Transport, R.T. Cheng (ed.), Coastal and Estuarine Studies, Vol. 38. Springer-Verlag, New York, 375–388 (1990).

Puget Sound is a fjord-like estuary in which bottom-water intrusions are a dominant circulation feature that play a major role in the replacement of water below sill depth within the estuary. New observations on the inside and outside of the entrance sill show that while intrusions occur during neap tides as previously thought, the onset of the intrusions occurs before the minimum in the neap tides. Calculations using a model with a balance between the longitudinal pressure gradient and vertical mixing suggest the onset is influenced by fluctuations in the horizontal density gradient caused by salinity variations across the sill. They also show that the resultant bottom inflow can be further modified by strong surface winds. Deep salinity changes seaward of the sill in the Strait of Juan de Fuca estuary appear to be the result of storms on the Pacific coast causing reversals of surface flow and variations in deep flow more than 135 km from the coast. Although Puget Sound is a glacially carved estuary, flow over the entrance sill in Admiralty Inlet has characteristics which resemble coastal plain estuaries; thus, these studies may have more general applications to time variations in lower layer flow at the mouth of other estuaries.

PM-017

CANNON, G.A., J.R. HOLBROOK, and D.J. PASHINSKI. Variations in the onset of bottom-water intrusions over the entrance sill of a fjord. Estuaries 13(1):31–42 (1990).

Puget Sound is a fjord-like estuary and bottom-water intrusions are major circulation features which play a dominant role in the replacement of water below sill depth. New observations on the inside and outside of the entrance sill show that, while intrusions occur during neap tides as previously thought, the onset of the intrusions is a result of fluctuations in the horizontal density gradient caused by salinity variations across the sill. Salinity changes outside the sill in the Strait of Juan de Fuca estuary appear to be the result of storms on the Pacific Coast causing reversals of surface flow and variations in deep flow more than 135 km from the coast. Previous observations have shown deep salinity variations midway along the Strait, but these are the first to show this effect can penetrate the full length of the Strait causing near-bottom salinity variations of sufficient magnitude to influence flow into Puget Sound. This influence probably occurs from the onset of storms in autumn through subsidence in spring, although occasional large storms occur in summer. Although Puget Sound is more characteristic of a fjord, the simple model calculations here suggest similar processes may occur in lower-layer flow at the mouth of coastal plain estuaries.

PM-018

CANNON, G.A., and D.J. PASHINSKI. Circulation near Axial Seamount. Journal of Geophysical Research 95(B8):12,823–12,828 (1990).

Year-long moored current measurements from 1987 to 1988 on the saddle (1860 m) between Axial Volcano and Brown Bear Seamount show an oscillating flow with a broadband frequency centered at about 4 days and a long-term average flow of about 4 cm/s southward. The measurements at sill depth also suggest a possible alternating exchange of water north and south of the Cobb-Eickelberg seamount chain with warmer water (0.05°C) coming from the north. However, measurements near the top of the volcano at about 1400 m show a weaker, but northward, mean flow, and the 4-day oscillation barely exists. Conductivity, temperature, and depth (CTD) observations on the east side of the volcano infer possible intensification of southward flow adjacent to the Juan de Fuca Ridge, similar to that found with combined CTD

and current meter observations about 100 km to the south. Southward flow is hypothesized along the entire east side of the ridge. On the west side the Axial-Brown Bear saddle may be near a convergence zone between southward and northward currents which then flow westward. The highly energetic environment on the saddle suggests other gaps in the ridge, and seamount chains may be important in determining the fate of the hydrothermal effluents. The general oceanic flow at the top of the caldera, however, is more tenuous, and the depth of change between these two regimes cannot be determined.

PM-019

COKELET, E.D., R.J. Stewart, and C.C. Ebbesmeyer. The annual mean transport in Puget Sound. NOAA TM ERL PMEL-92 (NTIS not yet available), 59 pp. (1990).

Puget Sound is modeled as a branched system of two-layered advective reaches separated by mixing zones. Fresh water and salt provide convenient tracers to calculate the annual mean layer transports. The technique utilizes historical records (1951–1956) of runoff and salinity which are analyzed with the aid of modern (principally 1970's) current meter records to provide the appropriate mass conserving landward- and seaward-flowing layer salinities for each reach. This is the first time that the long-term transports have been estimated simultaneously for the entire Strait of Juan de Fuca/Puget Sound system. With few exceptions the inferred transports agree well with estimates derived from scattered, shorter duration current observations. Uncertainties in the transports are estimated from uncertainties in the runoff, velocity profiles and salinities. The results provide the basis for future computations of refluxing and the steady state tracer concentrations and ages in the Sound.

PM-020

Davison, J., and D.E. HARRISON. A day-to-day comparison study of Seasat scatterometer winds with winds observed from islands in the tropical Pacific. NOAA TM ERL PMEL-91 (NTIS PB90-158791), 71 pp. (1989).

The Seasat scatterometer observed near-surface vector winds over the world ocean from an 800-km orbit by measuring radar backscatter from the wind-roughened surface. The early end of the mission in 1978 forestalled some of the planned ground-truth validation experiments; questions remain about the instrument's performance, in particular away from mid-latitudes. To increase the geographical range of SASS and *in situ* comparison experiments, we have compared data from islands in the tropical Pacific and contemporaneous scatterometer winds. We used satellite winds derived from two different wind vector algorithms (the signal processing that reduces the radar backscatter to wind speed and direction). The SASS-2 algorithm due to Wentz provides clearly better agreement in wind speed than the earlier SASS-1 algorithm. SASS-1 speeds tend to be higher than the island measurements by about 1 m s^{-1} while daily mean SASS-2 minus island wind speed differences average –0.07 m s^{-1} over the islands. RMS differences between SASS-2 and the daily mean island data average 1.7 m s^{-1}; the SASS-1 RMS differences average 2.2 m s^{-1}. Because the Seasat wind algorithms yield solutions with more than one possible direction, a single direction can only be selected from the others using ancillary information. We compared direction results from the objective selection method developed at the Goddard Laboratory for Atmospheres, as well as results from the somewhat artificial method of selecting the SASS direction closest in agreement with the comparison island direction. When averaged over tens of days the Goddard directions agree closely with the island observations. However, Goddard daily average directions exhibit considerably higher variance than those measured at the islands. The closest direction technique gives daily mean SASS minus island RMS direction differences averaging 20 degrees over the nine islands; the Goddard RMS differences average 52 degrees. Day-to-day comparison figures of vector winds from GLA SASS-1 and the islands permit detailed examination of the SASS-derived wind fields in the tropical Pacific near the comparison islands.

PM-021

Davison, J., and D.E. HARRISON. Comparison of Seasat scatterometer winds with tropical Pacific observations. Journal of Geophysical Research 95(C3):3403–3410 (1990).

The Seasat-A satellite scatterometer (SASS) observed near-surface vector winds over the world ocean from an 800-km orbit by measuring radar backscatter from the wind-roughened surface. The early end of the mission in 1978 forestalled some of the planned ground-truth validation experiments; questions remain about the instrument's performance, in particular away from mid-latitudes. To increase the geographical range of SASS and in situ comparison experiments, we have compared data from nine islands in the tropical Pacific and contemporaneous scatterometer winds. We used satellite winds derived from two different wind vector algorithms (the signal processing that reduces the radar backscatter to wind speed and direction). The SASS-2 algorithm due to Wentz provides clearly better agreement in wind speed than the earlier SASS-1 algorithm. SASS-1 speeds tend to be higher than the island measurements by about 1 m s^{-1}, while daily mean SASS-2 minus island wind speed differences average –0.07 m s^{-1}. The rms differences between SASS-2 and the daily mean island data average 1.7 m s^{-1}; the SASS-1 rms differences average 2.2 m s^{-1}. Because the Seasat wind algorithms yield solutions with more than one possible direction, a single direction can only be selected from the others using ancillary information. We compared direction results from the objective selection method developed at the Goddard Laboratory for Atmospheres, as well as results from the somewhat artifical method of selecting the SASS direction closest in agreement with the comparison island direction. When averaged over tens of days the Goddard directions agree closely with the island observations. However, Goddard daily mean directions exhibit considerably higher variance than those measured at the islands. The closest direction technique gives daily mean SASS minus island rms direction differences averaging 20°; the Goddard rms differences average 52°.

PM-022

EMBLEY, R.W., K.M. MURPHY, and C.G. FOX. High-resolution studies of the summit of Axial Volcano. Journal of Geophysical Research 95(B8):12,785–12,812 (1990).

Sea Beam bathymetry, Sea MARC I side scan (30 kHz), towed camera, and submersible data from Axial Volcano, Juan de Fuca Ridge (JdFR) have been integrated to produce detailed maps of the volcano's summit region in order to elucidate its volcanic and tectonic evolution. The proximity of Axial Volcano, the youngest edifice of the Cobb-Eickelberg Seamount Chain, to the JdFR superposes a hotspot-derived radial stress pattern onto the linear stress field of a mid-ocean ridge spreading center. The morphology of the summit of Axial Volcano reflects the differing eruptive styles produced from this superposition. Long rift zones begin at the edges of the caldera and extend as much as 75 km to the north and south. Axial Volcano has a distinct summit plateau similar to those found on many other submarine volcanos. The process by which summit plateaus are constructed is illustrated by the lava flows originating from the South Rift Zone, which have partially filled the southern half of the caldera and have smoothed the flanks. The summit plateau contains penetrative NE-SW fracturing that is approximately parallel to the JdFR. The unusual rectangular caldera is 3×8 km in size, and its trend is about 160°. Three possible mechanisms are discussed for the caldera's formation: (1) Canary Island-type "trapdoor" formation, (2) overlapping spreading center interaction, and (3) magma source migration. Although none of these models is fully compatible with the present data base, the overlapping spreading center model is preferred. Postcaldera volcanism probably began with the formation of the Central Caldera Eruptive Complex, which was characterized by relatively low-volume, high-viscosity flows. The most recent volcanism has apparently taken place along the northern and southern rift zones, which have erupted more fluid lavas resulting in areally extensive flows covering up to 60% of the caldera floor. Extensive low-temperature venting and areas of high-temperature venting near the northern and southern rift zones and caldera walls suggest a shallow magmatic source beneath the summit of Axial Volcano.

PM-023

FEELY, R.A., T.L. GEISELMAN, E.T. BAKER, G.J. MASSOTH, and S.R. HAMMOND. Distribution and composition of hydrothermal plume particles from the ASHES vent field at Axial Volcano, Juan de Fuca Ridge. Journal of Geophysical Research 95(B8):12,855–12,873 (1990).

In 1986 and 1987, buoyant and neutrally buoyant hydrothermal plume particles from the ASHES vent field within Axial Volcano were sampled to study their variations in composition with height above the seafloor. Individual mineral phases were identified using standard X ray diffraction procedures. Elemental composition and particle morphologies were determined by X ray fluorescence spectrometry and scanning electron microscopy/X ray energy spectrometry techniques. The vent particles were primarily composed of sphalerite, anhydrite, pyrite, pyrrhotite, chalcopyrite, barite, hydrous iron oxides, and amorphous silica. Grain size analyses of buoyant plume particles showed rapid particle growth in the first few centimeters above the vent orifice, followed by differential sedimentation of the larger sulfide and sulfate minerals out of the buoyant plume. The neutrally buoyant plume consisted of a lower plume, which was highly enriched in Fe, S, Zn, and Cu, and an upper plume, which was highly enriched in Fe and Mn. The upper plume was enriched in Fe and Mn oxyhydroxide particles, and the lower plume was enriched in suspended sulfide particles in addition to the Fe and Mn oxyhydroxide particles. The chemical data for the water column particles indicate that chemical scavenging and differential sedimentation processes are major factors controlling the composition of the dispersing hydrothermal particles. Short-term sediment trap experiments indicate that the fallout from the ASHES vent field is not as large as some of the other vent fields on the Juan de Fuca Ridge.

PM-024

FEELY, R.A., G.J. MASSOTH, E.T. BAKER, J.P. Cowen, M.F. LAMB, and K.A. Krogslund. The effect of hydrothermal processes on midwater phosphorus distributions in the northeast Pacific. Earth and Planetary Science Letters 96:305–318 (1990).

The distributions of dissolved, particulate and sedimentary phosphorus were measured in the region of the Juan de Fuca Ridge to determine the impacts of hydrothermal processes on the phosphorus cycle in the oceans. Significant negative dissolved phosphate anomalies, ranging from 0 to 60 nmol/l, were observed in the water column at depths between 1900 and 2300 db. The largest anomalies (< –50 nmol/l) were observed within the ridge axis. Corresponding positive particulate phosphorus anomalies and high concentrations of sedimentary phosphorus were also observed to have striking concentration gradients increasing towards the ridge axis. These observations provide strong evidence that phosphorus is being stripped from solution by scavenging reactions. Analysis of the particulate samples employing transmission electron microscopy techniques indicates that the scavenging occurs on newly-formed iron oxyhydroxides of hydrothermal origin. Mass balance calculations suggest that up to 12% of the total annual phosphorus sink in the oceans is a result of scavenging by hydrothermal emissions.

PM-025

FOX, C.G. Acoustic techniques for imaging the seafloor. In Gorda Ridge: A Seafloor Spreading Center in the United States Exclusive Economic Zone, G.R. McMurray (ed.). Springer-Verlag, New York, 169–178 (1990).

The recent development of sophisticated sonar systems for seafloor imaging allows analyses of terrain beyond simple bathymetric mapping. The SEABEAM multibeam sonar system produces full-coverage 12-kHz soundings, and much of the Gorda Ridge has been surveyed by the National Oceanic and Atmospheric Administration and the U.S. Navy. Complete-coverage digital bathymetry provides the

basic data for statistical modeling of seafloor roughness through spectral and fractal mathematical techniques. In addition to soundings, the SEABEAM system can provide fundamental information about bottom properties through evaluation of the backscattered acoustical signal. Side-scan sonar systems allow more detailed observations of the variability of acoustic properties. Available side-scan sonar data range from the broad (60-km swath) complete coverage of the GLORIA system collected by the U.S. Geological Survey to 10-km swath SeaMARC II and 5- to 0.5-km-wide SeaMARC I imaging, which produces pixel spot sizes of as little as 25 cm. The full-coverage, digital nature of these data allows the application of terrain classification techniques developed for satellite imagery. The validity of remote-imaging techniques can only be evaluated when compared to observational ground truth. A recently developed technique for geological mapping from bottom photography facilitates such comparisons.

PM-026

FOX, C.G. Consequences of phase separation on the distribution of hydrothermal fluids at ASHES vent field, Axial Volcano, Juan de Fuca Ridge. Journal of Geophysical Research 95(B8):12,923–12,926 (1990).

Recent studies of hydrothermal fluid chemistry at the Axial Seamount Hydrothermal Emissions Study (ASHES) vent field of Axial Volcano indicate separation of liquid and vapor phases during the migration of fluids to the seafloor. The brine phase liquid emanates from discrete sulfide chimneys, while fluid which has been through vapor phase separation flows diffusely from fissures in the surrounding basalt. One possible mechanism to explain this spatial segregation of the fluid phases is based on the relative permeability terms in the equations of two-phase flow. A qualitative model for the distribution of fluids observed at ASHES is postulated in which brine phase fluids are confined within flow conduits by a surrounding relative permeability barrier, while vapor phase fluids flow diffusely into the surrounding host rock.

PM-027

FOX, C.G. Evidence of active ground deformation on the mid-ocean ridge: Axial Seamount, Juan de Fuca Ridge, April–June 1988. Journal of Geophysical Research 95(B8):12,813–12,822 (1990).

Since September 1987 a precision bottom pressure recorder (BPR) has been deployed within the summit caldera of Axial Seamount on the central Juan de Fuca Ridge. The instrument is capable of measuring pressure to 1 mbar resolution and recording these measurements at 64 samples per hour for up to 15 months. After removal of oscillatory signals due to tidal and oceanographic effects and linear trends caused by sensor drift, any significant change in the pressure record should indicate a change of depth associated with vertical ground movement. In subaerial volcanic systems, such ground movements commonly indicate active inflation or deflation of underlying magma bodies and are frequently coincident with rift eruptions. Axial Seamount was selected for this pilot study for three primary reasons: (1) its tectonic setting, (2) the presence of a well-formed summit caldera, and (3) observational evidence of geologically recent volcanic activity. Results from the first 9 months of the BPR deployment revealed a significant change in pressure, which is interpreted to represent a 15-cm subsidence of the caldera floor during two 2- to 3-week periods in April-June 1988. Also during these periods, an anomalous decline in temperature at the site was recorded that is correlated with an apparent increase in current velocity at the Axial Seamount Hydrothermal Emissions Study (ASHES) vent field, suggesting vigorous advection of cold water into the caldera. Concurrent oceanographic data from Geosat and from current meter arrays do not indicate any large-scale oceanographic phenomena capable of generating these simultaneous events. One mechanism to explain simultaneous ground subsidence and temperature decline at the caldera center and increased bottom current at the caldera margin is the generation of a buoyant parcel of heated water in response to the intrusion or the eruption of magma associated with volcanic deflation. Such a parcel must have been sufficiently buoyant and proximal to induce horizontal entrainment currents capable of producing the bottom water conditions that were observed at both sites. Similar volcanic events also may have generated large midwater plumes that have been described previously along the southern Juan de Fuca Ridge.

PM-028

FOX, C.G., F.J. JONES, and T.-K. Lau. Constrained iterative deconvolution applied to SeaMARC I sidescan sonar imagery. IEEE Journal of Oceanic Engineering 15(1):24–31 (1990).

Images collected by any sidescan sonar system represent the convolution of the acoustic beam pattern of the instrument with the true echo amplitude distribution over the seafloor. At typical tow speeds, the 1.7° beam width of SeaMARC I results in multiple insonification of individual targets, particularly at the outside of the swath. A nonlinearly constrained iterative deconvolution technique developed for radar applications can be applied to SeaMARC I imagery to reduce the effect of the beam pattern and equalize the spectral content of the image across the swath. Since the deconvolution is implemented in the along-track direction, the registration of individual scan lines must be precisely corrected before the operator is applied. The deconvolution operator must be modeled to account for beam shape, vehicle speed, swath width, slant range, and ping rate. The method is numerically stable and increases the effective resolution of the image, but results in some loss of dynamic range. The technique is applied to target recognition and imagery from volcanic terrains of the central Juan de Fuca Ridge.

PM-029

Giese, B.S., and D.E. HARRISON. Aspects of the Kelvin wave response to episodic wind forcing. Journal of Geophysical Research 95(C5):7289–7312 (1990).

Episodes of westerly wind are an important aspect of surface stress variability in the western Pacific. During El Niño-Southern Oscillation periods, the presence of such wind episodes comprises much of the low-frequency relaxation of the trades over the central and western Pacific. In this paper we describe the oceanic Kelvin pulse response to a single idealized episode of westerly wind stress, using results from linear theory as well as from a 27-level general circulation model. Linear theory predicts that an episode of westerly wind will excite a train of equatorial trapped Kelvin pulses. The amplitude and longitudinal structure of the forced ocean Kelvin pulses varies as a function of baroclinic mode and the wind patch properties. Because of changing vertical thermal structure across the Pacific, the vertical structure of Kelvin pulses is altered as they propagate away from the forcing region. When stratification typical of the western and eastern Pacific is used, the conservation of energy flux predicts a reduction of surface currents associated with the first baroclinic mode and an enhancement of surface currents associated with the second baroclinic mode. The idealized wind anomaly is also used to drive an ocean general circulation model. When the wind anomaly is weak the model Kelvin response agrees with predictions of linear theory. For more realistic strong forcing there are three important deviations from linear theory: the amplitude of low baroclinic modes increases; the amplitude of higher baroclinic modes decreases; and the phase speed increases. In the presence of realistic oceanic background conditions, response in the equatorial waveguide is complicated by the equatorial undercurrent, a sloping thermocline and instability waves. Model sea surface temperature warming at the coast of South America is dominated by the second baroclinic mode, consistent with the results derived from linear theory.

PM-030

GONZALEZ, F.I., and E.N. BERNARD. Deep ocean tsunami and seismic wave observations: Three recent Gulf of Alaska events. Proceedings of Workshop XLVI, The 7th U.S.-Japan Seminar on Earthquake Prediction, Menlo Park, CA, 12–15 September 1988. USGS Open-File Report 90-98, 131–134 (1990).

No abstract.

PM-031

HAMMOND, S.R. Relationships between lava types, seafloor morphology, and the occurrence of hydrothermal venting in the ASHES vent field of Axial Volcano. Journal of Geophysical Research 95(B8):12,875–12,893 (1990).

Deep-towed and submersible photographic surveys within the caldera of Axial Volcano have been integrated with high-resolution bathymetry to produce a geological map of the most active vent field (Axial Seamount Hydrothermal Expeditions (ASHES)) in the caldera. The ASHES vent field encompasses an approximately 200 m × 1200 m area of active venting which is located adjacent to the southwest caldera wall. Locations for over 2000 photographs in and near the vent field were determined using a seafloor transponder network. Then each photograph was described utilizing a classification system which provides detailed information concerning lava type, hydrothermal activity, sediment cover, geological structure, and biology. Resulting data were entered into a digital data base, and computer-generated maps were created that portray spatial relationships between selected geological variables. In general, the entire ASHES field is characterized by pervasive low-temperature venting. The most vigorous venting is concentrated in an approximately 80 m × 80 m area where there are several high-temperature vents including some which are producing high-temperature vapor-phase fluids derived from a boiling hydrothermal system. Lava types within the ASHES vent field are grouped into three distinct morphologies: (1) smooth (flat-surfaced, ropy, and whorled) sheet flows, (2) lobate flows, and (3) jumbled-sheet flows. The most intense hydrothermal venting is concentrated in the smooth sheet flows and the lobate flows. The location of the ASHES field is mainly attributable to faulting which defines the southwest caldera wall, but the concentration of intense venting appears to be related also to the spatial distribution of lava types in the vent field and their contrasting permeabilities. Other structural trends of faults and fissures within the field also influence the location of individual vents.

PM-032

HARRISON, D.E. Post World War II trends in tropical Pacific surface trades. Journal of Climate 2(12):1561–1563 (1989).

Multidecadal time series of surface winds from central tropical Pacific islands are used to compute trends in the trade winds between the end of WWII and 1985. Over this period, averaged over the whole region, there is no statistically significant trend in speed of zonal or meridional wind (or pseudostress). However, there is some tendency, within a few degrees of the equator, toward weakening of the easterlies and increased meridional flow toward the equator. Anomalous conditions subsequent to the 1972–73 ENSO event make a considerable contribution to the long-term trends. The period 1974–80 has been noted previously to have been anomalous, and trends over that period are sharply greater than those over the longer records.

PM-033

HARRISON, D.E., B.S. Giese, and E.S. Sarachik. Mechanisms of SST change in the equatorial waveguide during the 1982–83 ENSO. Journal of Climate 3(2):173–188 (1990).

Four different datasets of monthly mean near-equatorial Pacific sea surface temperature for 1982–83 are compared, and the space-time regions for which there was consensus that cooling or warming took place, are determined. There was consensus that warming took place east of the date line, averaged over the period July-December 1982, and that the warming progressed eastward from the central Pacific.

There was also consensus that weak cooling took place in April 1983, and that substantial cooling occurred in June-July 1983, generally over the central and eastern Pacific. However, the analyses tend to agree on the sign of SST change only in periods of cooling or warming in excess of 1°C/month; quantitative agreement at the level of 0.5°C/month or better is almost never found. SST changes in five ocean-circulation model hindcasts of the 1982–83 period (differing only in that each used a different analyzed monthly mean surface wind stress field to drive the ocean), are compared with the observations and with each other. There is agreement that net warming occurred in the July–December 1982 period and cooling in mid-1983. The heat budgets of these experiments indicate that the major model central Pacific warmings occurred primarily from anomalous eastward surface advection of warm water. Further, east zonal advection remains significant, but a diminished cooling tendency from meridional advection can also be important; different hindcasts differ on the relative importance of these terms. Surface heat flux changes do not contribute to the warmings. The reduced cooling tendency from meridional advection is consistent with diminished surface Ekman divergence, suggesting that southward transport of warm north equatorial counter current water was not a major factor in the model warmings. The hindcasts do not agree on the relative importance of local or remote forcing of the eastward surface currents; while there is clear evidence of remote forcing in some hindcasts in particular regions, local forcing is also often significant. The main 1983 midocean cooling began because of increased vertical advection of cool water; but once cooling began horizontal advection often contributed. Further east, where the easterlies generally return later than they do in midocean, upwelling and horizontal advection all can be important. Again no model consensus exists concerning the details of SST evolution. Because the observations do not agree on the sign of SST change during much of the 1982–83 period, improved SST data is needed in order to document the behavior of the ocean through future ENSO periods. Better forcing data will be needed to carry out improved ocean-model validation studies, and to explore the mechanisms likely responsible for SST change through entire ENSO cycles.

PM-034

HARRISON, D.E., and D.S. Luther. Surface winds from tropical Pacific islands—climatological statistics. Journal of Climate 3(2):251–271 (1990).

Multidecadal time series of surface wind observations from tropical Pacific islands have been examined in order to investigate the space and time scales of variability. Climatological monthly means and variances are compared with comparable means and variances derived from ship observations; usually the means agree to within ~1 m s^{-1} in speed and ~10 degrees in direction. Annual and semiannual cycles differ in detail. Island zonal wind variances are often significantly larger, by up to 10 m^2 s^{-2} near the equator between September and December; because of the spatial coherence of the island results, these discrepancies are believed to result from the poor high-frequency sampling typical of ship data. A substantial near-equatorial zonal wind variance maximum is shown to be related to ENSO period variability; excluding ENSO time periods leaves a relatively spatially uniform variance of ~5 m^2 s^{-2} over a broad region. The frequency distribution of variance, derived from daily-averaged data, exhibits considerable geographical variation. Within a few degrees of the equator the most energetic zonal wind variability is found in a broad band extending from about 3- to 60-day periods, with maximum at about 10 days; there is also significant interannual power in records located west of 170°W. There is occasionally a local variance maximum in the range of 30- to 60-day periods. Within this near-equatorial region, the meridional wind variance is roughly half the zonal wind variance and is found primarily between about 3-day and 6-day periods and at the annual period. Poleward of about 5 degrees of latitude, the interannual variability in zonal wind diminishes sharply, and the zonal and meridional wind variances become increasingly comparable. The zonal wind energy level in the 3- to 60-day band decreases as one moves farther from the equator, until the more energetic winds typical of subtropical latitudes arise. Coherence calculations typically show zonal wind coherence significant at the 95% level at all energetic periods when islands are within 200–300 km of each other meridionally, and within 1000–1500 km zonally. The meridional wind tends to be less coherent. A minimal sampling array for tropical surface wind variability in this region should have meridional sampling about every 2° and zonal sampling about every 15° for the zonal wind, and perhaps half these distances for the meridional wind.

PM-035

HAYES, S.P. The Tropical Atmosphere Ocean Array—TOGA-TAO. Proceedings of the International Symposium on Japanese Pacific Climate Study (JAPACS), Center for Institutes, Tsukuba City, Japan, October 19–20, 1989, 67-1 to 67-3 (1989).

No abstract.

PM-036

HAYES, S.P., M.J. MCPHADEN, and J.M. Wallace. The influence of sea-surface temperature on surface wind in the eastern equatorial Pacific: Weekly to monthly variability. Journal of Climate 2(12):1500–1506 (1989).

Temporal correlations between near-equatorial surface wind and sea-surface temperatures (SST) at 110°W in the eastern Pacific Ocean are investigated using data from an array of moored sensors between 5°N and 5°S. The signature of tropical instability waves with periods of 20–30 days is apparent in time series of SST and both the meridional and zonal wind components. Results indicate the existence of a band of pronounced horizontal divergence in the surface wind field associated with the large meridional SST gradient (equatorial front) normally located just north of the equator. Perturbations of the equatorial front by the instability waves induce fluctuations in the overlying winds. Evidence of the air-sea coupling is stronger in time series of the meridional gradients of wind and SST than between time series of the variables themselves. The meridional differencing serves as a high-pass filter in the space domain, which removes planetary-scale wind fluctuations that are unrelated to the local SST perturbations. The wind fluctuations observed in association with tropical instability waves

are on the order of 1–2 m s^{-1}. These results indicate that SST variability on weekly to monthly time scales forces perturbations in the surface wind field. It is suggested that the principal coupling mechanism in this region is the modification of the atmospheric boundary layer stratification. Over the equatorial cold SST tongue the vertical wind shear within the lowest 100 m of the atmosphere is strong and the surface winds are conspicuously weak. As the air flows northward across the equatorial front the boundary layer becomes destabilized, momentum is mixed downward, and the surface winds increase.

PM-037

HAYES, S.P., M.J. MCPHADEN, J.M. Wallace, and J. Picaut. The influence of sea-surface temperature on surface wind in the equatorial Pacific Ocean. Proceedings of the Western Pacific International Meeting and Workshop on TOGA COARE, Nouméa, New Caledonia, May 24–30, 1989. ORSTOM, 543–547 (1989).

No abstract.

PM-038

Hildebrand, J.A., J.M. Stevenson, P.T.C. Hammer, M.A. Zumberge, R.L. Parker, C.G. FOX, and P.J. MEIS. A seafloor and sea surface gravity survey of Axial volcano. Journal of Geophysical Research 95(B8):12,751–12,763 (1990).

Seafloor and sea surface gravity measurements are used to model the internal density structure of Axial Volcano. Seafloor measurements made at 53 sites within and adjacent to the Axial Volcano summit caldera provide constraints on the fine-scale density structure. Shipboard gravity measurements made along 540 km of track line above Axial Volcano and adjacent portions of the Juan de Fuca ridge provide constraints on the density over a broader region and on the isostatic compensation. The seafloor gravity anomalies give an average density of 2.7 g cm^{-3} for the uppermost portion of Axial Volcano. The sea surface gravity anomalies yield a local compensation parameter of 23%, significantly less than expected for a volcanic edifice built on zero age lithosphere. Three-dimensional ideal body models of the seafloor gravity measurements suggest that low-density material, with a density contrast of at least 0.15 g cm^{-3}, may be located underneath the summit caldera. The data are consistent with low-density material at shallow depths near the southern portion of the caldera, dipping downward to the north. The correlation of shallow low-density material and surface expressions of recent volcanic activity (fresh lavas and high-temperature hydrothermal venting) suggests a zone of highly porous crust. Seminorm minimization modeling of the surface gravity measurements also suggest a low-density region under the central portion of Axial Volcano. The presence of low-density material beneath Axial caldera suggests a partially molten magma chamber at depth.

PM-039

Huebert, B.J., T.S. BATES, A. Bandy, S. Larsen, and R.A. Duce. Planning for chemical air-sea exchange research. Eos, Transactions of the American Geophysical Union 71(35):1051–1057 (1990).

No abstract.

PM-040

Incze, L.S., P.B. Ortner, and J.D. SCHUMACHER. Microzooplankton, vertical mixing and advection in a larval fish patch. Journal of Plankton Research 12(2):365–379 (1990).

A large (~30 × 75 km) patch of larval walleye pollock, *Theragra chalcogramma*, was located south of the Alaska Peninsula during May 1986. A drifter deployed in this patch followed an anticyclonic path consistent with dynamic topography. Changes in community composition and vertical distribution of microzooplankton >40 μm were sampled for 4 days alongside this drifter to examine feeding conditions for larvae. Biological and physical changes during the first 2 calm days revealed substantial small-scale variability within the larger circulation pattern. Changes during the last 2 days were dominated by vertical mixing due to strong winds. Despite mixing, prey concentrations remained adequate for feeding by larval pollock as determined by laboratory studies. A satellite-tracked drifter replaced the first drifter and was still located within the patch 6 days later. Overall distributions of larvae and movements of the drifters show a net translation of 7.8 km day^{-1} south-westward, but details of the study reveal complex interactions between coastal waters and a coastal current. During the 10-day period there was an increase in standard length of the larval fish population of 0.13 mm day^{-1} and a decline in abundance of ~7.6% day^{-1}. Both calculated rates must be underestimates due to continuing recruitment of small larvae from hatching eggs.

PM-041

Johnson, H.P., and R.W. EMBLEY. Axial Seamount: An active ridge axis volcano on the central Juan de Fuca Ridge. Journal of Geophysical Research 95(B8):12,689–12,696 (1990).

No abstract.

PM-042

Johnson, J.E., R.H. GAMMON, J. LARSEN, T.S. BATES, S.J. Oltmans, and J.C. Farmer. Ozone in the marine boundary layer over the Pacific and Indian Oceans: Latitudinal gradients and diurnal cycles. Journal of Geophysical Research 95(D8):11,847–11,856 (1990).

Ozone concentrations in the atmospheric boundary layer of the Pacific and Indian Oceans were measured on four separate oceanographic research cruises (July 1986, May to August 1987, April to May 1988). These measurements show a distinct zone of near zero (≤3 ppb) ozone concentration in the central equatorial Pacific in April-May, with ozone increasing in this region over the next 4 months. The seasonal observed change in the latitudinal gradient of ozone is consistent with previous ozone measurements at Hilo and Samoa by *Oltmans and Komhyr* [1986] and predictions from an atmospheric general circulation model study [*Levy et al.*, 1985]. A significant diurnal cycle of ozone was found in almost all locations with a maximum near sunrise, a minimum in the late afternoon, and a peak-to-peak amplitude of 1 to 2 ppb (10–20%), similar to that predicted by a photochemical model in the low NO_x limit [*Thompson and Lenschow*, 1984].

PM-043

Kessler, W.S. Observations of long Rossby waves in the northern tropical Pacific. Journal of Geophysical Research 95(C4):5183–5217 (1990).

Long baroclinic Rossby waves are potentially important in the adjustment of the tropical Pacific pycnocline to both annual and interannual wind stress curl fluctuations. Evidence for such waves is found in variations of the depth of the 20°C isotherm in the northern tropical Pacific during 1970–1987. A total of 199,067 bathythermograph profiles have been compiled from the archives of several countries; the data coverage is dense enough that westward propagating events may be observed with a minimum of zonal interpolation. After extensive quality control, 20°C depths were gridded with a resolution of 2° latitude, 5° longitude, and bimonths; statistical parameters of the data were estimated. A simple model of low-frequency quasi-geostrophic pycnocline variability allows the physical processes of Ekman pumping, the radiation of long (nondispersive) Rossby waves due to such pumping in midbasin, and the radiation of long Rossby waves from the observed eastern boundary pycnoline depth fluctuations. Although the wind stress curl has very little zonal variability at the annual period in the northern tropical Pacific, an annual fluctuation of 20°C depth propagates westward as a long Rossby wave near 5°N and 14°–18°N in agreement with the model hindcast. Near the thermocline ridge at 10°N, however, the annual cycle across the basin is dominated by local Ekman pumping. The wave-dominated variability at 5°N weakens the annual cycle of geostrophic transport of the North Equatorial Countercurrent in the western Pacific. El Niño events are associated with westerly wind anomalies concentrated in the central equatorial Pacific; upwelling wind stress curl is generated in the extraequatorial tropics by these westerlies. Long upwelling Rossby waves forced by this curl pattern were observed to raise the western Pacific thermocline well outside the equatorial waveguide in the later stages of El Niños, consistent with the simple long-wave model. The observations suggest that although simple reflection of the long Rossby waves from the western boundary is not the major process affecting subsequent development on the equator, it is likely that the extraequatorial waves play some role in setting the timescale of ENSO events.

PM-044

Kiene, R.P., and T.S. BATES. Biological removal of dimethyl sulphide from sea water. Nature 345(6277):702–705 (1990).

Dimethyl sulphide (DMS) is an important sulphur-containing trace gas in the atmosphere. It is present in oceanic surface waters at concentrations sufficient to sustain a considerable net flux of DMS from the oceans to the atmosphere, estimated to comprise nearly half of the global biogenic input of sulphur to the atmosphere. DMS emitted from the oceans may be a precursor of tropospheric aerosols and of cloud condensation nuclei in the remote marine atmosphere, thereby affecting the Earth's radiative balance and thus its climate. Relatively little is known, however, about the biogeochemical and physical processes that control the concentration of DMS in sea water. Here we present data from incubation experiments, carried out at sea, which show that DMS is removed by microbial activity. In the eastern, tropical Pacific Ocean, DMS turnover is dominated by biological processes, with turnover times for biological DMS removal generally more than ten (3–430) times faster than turnover by ventilation to the atmosphere. Thus biological consumption of DMS seems to be a more important factor than atmospheric exchange in controlling DMS concentrations in the ocean, and hence its flux to the atmosphere. These results have significant implications for climate feedback models involving DMS emissions, and highlight the importance of the microbial food web in oceanic DMS cycling.

PM-045

Landsteiner, M.C., M.J. MCPHADEN, and J. Picaut. On the sensitivity of Sverdrup transport estimates to the specification of wind stress forcing in the tropical Pacific. Journal of Geophysical Research 95(C2):1681–1691 (1990).

We use Sverdrup dynamics to estimate geostrophic transports between 20°N and 20°S in the tropical Pacific Ocean averaged over the period 1979–1981. Three wind stress products are used to force the model. Results are compared to geostrophic transports computed along expendable bathythermograph transects in the western, central, and eastern Pacific for the same period. Depending on the choice of wind stress, modeled transports may differ from the observations by a factor of 2 and, in some cases, flow is opposite to that observed. Possible limitations of the Sverdrup theory are discussed; however, we conclude that detailed and accurate simulation of the general circulation in the tropical Pacific is limited more by the uncertainties in presently available estimates of the surface wind stresses than by deviations from Sverdrup balance.

PM-046

LARSEN, J.C. Transfer functions: Smooth robust estimates by least-squares and remote reference methods. Geophysical Journal International 99:645–663 (1989).

A method is described for finding the magnetotelluric transfer function that has the least amount of curvature consistent with most of the data and with a 1-D conductivity interpretation over the widest possible frequency range. This could be called an "Occam" transfer function. It is represented by the transfer function for the best fitting 1-D conductivity model times a distortion function. The latter permits smooth departures of the transfer function from the 1-D case if the data are inconsistent with a 1-D interpretation. The transfer function, for single-station or remote reference magnetotelluric data, is found by a method of successive iterations that is found to converge within six to eight iterations. The estimate of the transfer functions is made robust by using frequency and time weights that remove the effects of outliers in the time and frequency domain. If the weighted residuals for remote reference data satisfy certain necessary conditions for uncorrelated noise then the contribution to the noise by the electric and magnetic data can be estimated and used to evaluate the least-squares and remote reference estimates. Examples illustrate the application of this method to artificial and real data. The latter consist of hourly cable voltage data from the Florida Straits, 1/256-s remote reference magnetotelluric survey data from the Phillippines and daily magnetic data from Tucson and Honolulu.

PM-047

LARSEN, J.C. Transport measurements from in service undersea telephone cables. Proceedings, Workshop on Scientific Uses of Undersea Cables, Honolulu, HI, Jan. 30–Feb. 1, 1990. Incorporated Research Institutions for Seismology (IRIS)/Joint Oceanographic Institutions (JOI), 117–130 (1990).

Eight years of continuous recordings of the voltages across the Florida Straits using an abandoned cable making ocean contact near Jupiter, Florida and Settlement Point, Grand Bahama Island, have shown that this is an inexpensive method for accurately monitoring the transport fluctuations of the Florida Current (Larsen & Sanford 1985, Larsen 1990). The conversion of the voltages to transports (24.30 ± 0.53 Sv/V) (1 Sverdrup = 1 Sv = 10^6 m^3/s) was determined by a comparison with 130 days of transport values derived from velocity profiling data. The rms misfit is 0.7 Sv which is about the accuracy of the profiling derived transports. Undersea telephone cables, including the new fiber optic cables, can also, in principle, be used to determine the voltage difference between the cable-ocean contacts by recording the power voltage and current. The success of the abandoned cable in monitoring the transport, the existence of undersea telephone cables and the expense of deploying new cables justifies a serious effort to investigate whether in service undersea telephone cables can be used for monitoring ocean currents.

PM-048

Latif, M., J. Biercamp, H. von Storch, M.J. MCPHADEN, and E. Kirk. Simulation of ENSO related surface wind anomalies with an atmospheric GCM forced by observed SST. Journal of Climate 3(5):509–521 (1990).

The ECMWF-T21 atmospheric GCM is forced by observed near-global SST from January 1970 to December 1985. Its response in low level winds and surface wind stress over the Pacific Ocean is compared with various observations. The time dependent SST clearly induces a Southern Oscillation (SO) in the model run which is apparent in the time series of all variables considered. The phase of the GCM SO is as observed, but its low frequency variance is too weak and is mainly confined to the western Pacific. Because of the GCM's use as the atmospheric component in a coupled ocean-atmosphere model, the response of an equatorial oceanic primitive equation model to both the modeled and observed wind stress is examined. The ocean model responds to the full observed wind stress forcing in a manner almost identical to that when it is forced by the first two low frequency EOFs of the observations only. These first two EOFs describe a regular eastward propagation of the SO signal from the western Pacific to the central Pacific within about a year. The ocean model's response to the modeled wind stress is too weak and similar to the response when the observed forcing is truncated to the first EOF only. In other words, the observed SO appears as a sequence of propagating patterns but the simulated SO as a standing oscillation. The nature of the deviation of the simulated wind stress from observations is analyzed by means of Model Output Statistics (MOS). It is shown that a MOS-corrected simulated wind stress, if used to force an ocean GCM, leads to a significant enhancement of low frequency SST variance, which is most pronounced in the western Pacific.

PM-049

MANGUM, L.J., S.P. HAYES, J.M. Toole, Z. Wang, S. Pu, and D. Hu. Thermohaline structure and zonal pressure gradient in the western equatorial Pacific. Journal of Geophysical Research 95(C5):7279–7288 (1990).

Two recent sections of temperature and salinity along the equator in the western Pacific were examined in the context of the historical hydrographic data. Both sections occurred during the December-February period when climatological mean winds are northwesterly. The historical data indicate that the zonal sea surface slope responds to the seasonal change in wind stress. During the southeasterly monsoon the historical mean surface relative to 500 dbar dynamic height slopes upwards from east to west; during the northwesterly monsoon this slope reverses. Vertical profiles of the mean zonal pressure gradient relative to 500 dbar suggest that the wind influence may extend quite deep in the water column. The two quasi-synoptic sections both indicated that the sea level sloped downward towards the west between 155°E and 140°E. The sign of this slope agrees with the historical seasonal mean; however, the zonally averaged sea level in this westernmost region

changed by nearly 0.1 dyn m between sections. Upper ocean water properties and stratification confirmed the importance of salinity in determining mixed layer depth. Comparisons of repeat stations collected during a 16-day period indicated relatively rapid changes in near surface properties and the importance of lateral advection.

PM-050

MCPHADEN, M.J. Comment on "Rossby-gravity waves in the central equatorial Pacific Ocean during the NORPAX Hawaii-to-Tahiti Shuttle Experiment" by S.M. Chiswell and R. Lukas. Journal of Geophysical Research 95(C1):805–806 (1990).

No abstract.

PM-051

MCPHADEN, M.J. Moored equatorial current measurements in the Pacific Ocean. Proceedings of the International Symposium on Japanese Pacific Climate Study (JAPACS), Center for Institutes, Tsukuba City, Japan, 19–20 October 1989, 57-1 to 57-5 (1989).

No abstract.

PM-052

MCPHADEN, M.J. On the relationship between winds and upper ocean temperature variability in the western equatorial Pacific. Proceedings of the Western Pacific International Meeting and Workshop on TOGA COARE, Nouméa, New Caledonia, May 24–30, 1989. ORSTOM, 283–290 (1989).

In this study we examine the relationship between winds and upper ocean temperature variability using data from an equatorial mooring at 0°, 165°E. The analysis focuses primarily on daily to monthly time scale variations during 1986 and 1987 at the height of the 1986–87 El Niño/Southern Oscillation event. The period is one of high mean sea surface temperatures (≥29°C) and frequent outbreaks of westerly winds. We infer that in general wind-driven vertical advection and entrainment from the thermocline are not likely to be important processes affecting surface temperatures in the western equatorial Pacific. Conversely, we conclude that variations in evaporative cooling may account for a significant percentage of the observed surface layer temperature variance during the study period.

PM-053

MCPHADEN, M.J., H.P. FREITAG, and A.J. SHEPHERD. Moored salinity time series measurements at 0°, 140°W. Journal of Atmospheric and Oceanic Technology 7(4):568–575 (1990).

This study describes moored salinity time series measurements in a biologically productive equatorial upwelling regime in the Pacific Ocean (0°, 140°W). Data were collected at 26 m and at 100 m for 13 months during 1987–1988 using four SEACAT conductivity and temperature recorders equipped with optional antifouling attachments. Laboratory pre- and post-deployment calibrations indicate that the instrumental drift in SEACAT salinity measurements was typically <0.015 psu with a maximum of 0.055 psu for sequential 6–7 month long mooring deployments. Root mean square (rms) differences with CTD casts taken within a few nautical miles of the moorings were ~0.05 psu. These values are an order of magnitude smaller than the observed range of salinity variations. Little biogenic material was found on the SEACAT sensors on recovery. Thus, we infer that the antifouling attachments used were effective and that similar favorable results using SEACATs can be expected at other times and places in equatorial upwelling regimes.

PM-054

MCPHADEN, M.J., and S.P. HAYES. Variability in the eastern equatorial Pacific Ocean during 1986–1988. Journal of Geophysical Research 95(C8):13,195–13,208 (1990).

We examine variability in the eastern equatorial Pacific during 1986–1988 using conductivity-temperature-depth data, velocity and temperature data from equatorial moorings between 110°W and 140°W, and wind data from a basin scale zonal array of islands and moorings between 110°W and 165°E. The period studied coincides with the El Niño/Southern Oscillation (ENSO) event of 1986–1987 and a subsequent cold event in 1988. Weak warm sea surface temperature anomalies first appeared in the eastern equatorial Pacific in mid-1986 and increased to >1°C in September-November 1986 in association with a 30 cm s^{-1} weakening of the South Equatorial Current and a 20- to 40-m depression of the thermocline. These warm anomalies lasted until early 1988, after which a large-scale shoaling of the thermocline led to sea surface temperatures more than 3°C colder than climatology. Year-to-year fluctuations in the eastern Pacific were related primarily to zonal wind variations in the central and western Pacific. Westerly wind stress anomalies of 0.02–0.05 N m^{-2} were observed between 140°W and 165°E from the latter half of 1986 until the end of 1987; these were replaced by easterly wind anomalies of similar magnitude between 157°W and 165°E in 1988. Energetic intraseasonal fluctuations with periods of 2–3 months were also prominent in zonal current, temperature, and dynamic height time series. These fluctuations propagate eastward at approximately first baroclinic mode Kelvin wave phase speeds and are forced west of the date line by episodes of westerly winds. Extrema in several oceanic variables occurred in association with these waves, though their precise dynamical link to the ENSO cycle is unclear from our data. Sea surface temperature and thermocline

depth anomalies at 0°, 110°W were less pronounced during the 1986–87 ENSO than during the 1982–83 ENSO; the Equatorial Undercurrent, though weaker than normal in early 1987, did not disappear as it did in early 1983.

PM-055

MCPHADEN, M.J., S.P. HAYES, L.J. MANGUM, and J.M. Toole. Variability in the western equatorial Pacific Ocean during the 1986–87 El Niño/Southern Oscillation event. Journal of Physical Oceanography 20(2):190–208 (1990).

We describe variability in the western Pacific Ocean during the 1986–87 El Niño/Southern Oscillation (ENSO) event, with emphasis on time series measurements of currents, temperature, sea level and winds near the equator at 165°E. Zonal winds were anomalously westerly from mid-1986 to late 1987 and were punctuated by 2–10 m s^{-1} episodes of westerlies lasting about 10 days to 2 months. Zonal currents in the upper 100-m surface layer responded to these wind variations typically within a week, in some cases with speeds exceeding 100 cm s^{-1} to the east. Zonal current variations in the thermocline below 100 m were generally less coherent with the local winds than currents near the surface. They were also generally less variable, although the Equatorial Undercurrent disappeared for 3–4 weeks in October-November 1987 at a time when the normal eastward directed zonal pressure gradient force reversed along the equator. Periods of intense and prolonged eastward flow in the surface layer were associated with a decrease in sea level by 10–20 cm at the end of 1986 and in May-August, 1987. Similarly, significant westward flow near the surface and in the thermocline in September-November 1987 was accompanied by rising sea level and a westward migration from the date line of surface waters >30°C. These results suggest that wind-driven zonal currents at the equator were important in the evolution of the mass and heat balance of the western Pacific during the 1986–87 ENSO. Conversely, meridional wind stress and meridional velocity energy levels at periods longer than 100 days on the equator were 5–10 times weaker than in the zonal direction and less obviously related to the evolution of the 1986–87 ENSO.

PM-056

MCPHADEN, M.J., H.B. MILBURN, A.I. NAKAMURA, and A.J. SHEPHERD. PROTEUS—Profile Telemetry of Upper Ocean Currents. Proceedings MTS '90, Marine Technology Society, Washington, D.C., 353–357 (1990).

In this paper we describe the development of a real-time capability for satellite transmission of acoustic Doppler current profiler (ADCP) data from deep water surface moorings. This development, which we call PROTEUS (PROfile TElemetry of Upper ocean currentS), consists of a downward-looking, surface buoy-mounted 153.6 kHz RDI ADCP with an Argos satellite telemetry link. Our efforts have been motivated by a need for real-time velocity profiles in support of short-term climate studies of El Niño and the Southern Oscillation. The first PROTEUS mooring was successfully deployed in April 1990 at 0°, 140°W as part of NOAA's EPOCS program. We describe the mooring configuration, the Argos data format, and the velocity data itself from the first 6 weeks of deployment. We also present a preliminary intercomparison of PROTEUS data from the first depth bin below the surface with data collected in real-time from a Vector Measuring Current Meter moored 17 km to the east of the PROTEUS mooring.

PM-057

MCPHADEN, M.J., and P. Ripa. Wave-mean flow interactions in the equatorial ocean. Annual Reviews of Fluid Mechanics 22:167–205 (1990).

No abstract.

PM-058

MILBURN, H.B., and E.N. BERNARD. Deep ocean tsunami observations. Proceedings, IRIS/JOI Workshop on Scientific Uses of Undersea Cables, Honolulu, HI, Jan. 30–Feb. 1, 1990, 69–73 (1990).

No abstract.

PM-059

Mobley, C.D. A numerical model for the computation of radiance distributions in natural waters with wind-roughened surfaces. Limnology and Oceanography 34(8):1473–1483 (1989).

A numerical technique is presented for computing radiance distributions in natural waters that have wind-blown surfaces and depth-dependent inherent optical properties. Input to the numerical model consists of the radiance distribution incident on the air-water surface from above, the wind velocity, which specifies the state of randomness of the air-water surface via a wind speed-wave slope spectrum, the volume scattering and volume attenuation functions of the water body as functions of depth and wavelength, and the type of bottom boundary. Primary output from the model consists of directionally discretized radiances as functions of wavelength, direction, and depth throughout and above the water body.

PM-060

MOFJELD, H.O. Long-term trends and interannual variations of sea level in the Pacific Northwestern region of the United States. Oceans '89 Proceedings, Seattle, WA, September 18–21, 1989, Vol. 1: Fisheries, Global Ocean Studies, Marine Policy and Education, Oceanographic Studies. Marine Technology Society, IEEE Publication Number 89CH2780-5, 228–230 (1989).

Long-term observations of sea level at sites in the inland and coastal waters of Washington State provide a useful case study of how sea level trends relative to the land can vary in magnitude and even in sign within the same geographical region. Within 200 km, increases in relative sea level occur at Seattle (1.9 mm/yr) in Puget Sound and Friday Harbor (1.0 mm/yr) to the north, while a decrease occurs at Neah Bay (–1.6 mm/yr) near the coast. These trends are comparable in magnitude with the average (1.5 mm/yr) for the coast of the United States. Tectonic processes seem to account for the variations in trend. The smaller trend at Friday Harbor is consistent with more intense glacial rebound due to heavier ice loading during the last ice age, while decreasing relative sea level at Neah Bay is consistent with uplift due to subduction of the Juan de Fuca Plate under the North American Plate. Superimposed on the trends are interannual variations in sea level associated with El Niño events (e.g., 1914–15, 1940–41 and 1982–83) in which higher oceanic temperatures increased sea level (up to 30 cm for the 1982–83 winter period). Interannual variations in atmospheric pressure and wind forcing also cause large variations in sea level from year to year, predominantly in winter.

PM-061

NAKAMURA, A.I., R. NEWMAN, and H.B. MILBURN. Florida current cross-stream voltage measurement methodology and instrumentation. Oceans '89 Proceedings, Seattle, WA, September 18–21, 1989, Vol. 5: Diving Safety and Physiology, Ocean Engineering/Technology. Marine Technology Society, IEEE Publication Number 89CH2780-5, 1584–1587 (1989).

No abstract.

PM-062

OVERLAND, J.E. Prediction of vessel icing for near-freezing sea temperatures. Weather and Forecasting 5(1):62–77 (1990).

The operational NOAA categorical vessel icing algorithm is evaluated with regard to advances in understanding of the icing process and forecasting experience. When sea temperatures are <2–3°C above the saltwater freezing point there is the likelihood of supercooling of the spray during its trajectory and extreme ice accretion on topside structures. The NOAA algorithm shows excellent results when compared to a new cold-water dataset from the Labrador Sea (mean sea temperature of –1.3°C), even though the algorithm was developed from an Alaskan dataset with a mean sea temperature of 3.6°C. A rederived algorithm from the combined data set is nearly identical to the operational algorithm. The influence of sea temperature in the NOAA model is consistent with the supercooling hypothesis and an additional icing category of extreme is recommended for the algorithm. Severe icing in the Bering Sea, Gulf of Alaska, and Sea of Japan is primarily caused by extreme cold-air advection, while low sea temperatures contribute to severe icing in the Labrador Sea, Denmark Strait, and Barents Sea. Indirect verification showed that NOAA provided excellent forecasts to over 140 fishing vessels in Alaskan waters during late January 1989, the worst icing episode of the decade. This case suggests that current-generation atmospheric models are capable of providing reliable 36-h forecasts of cold-air advection, and thus indicating regions of heavy icing. A wave height/wind speed threshold for the onset of topside icing is 5 m s^{-1} for a 15-m vessel, 10 m s^{-1} for a 50-m trawler and 15 m s^{-1} for a 100-m vessel, developed from seakeeping theory. These wind speeds are exceeded 83%, 47% and 15%, respectively, during February in the Bering Sea.

PM-063

PAULSON, A.J., M.M. Benjamin, and J.F. Ferguson. Zn solubility in low carbonate solutions. Water Research 23(12):1563–1569 (1989).

While the importance of several metal basic carbonates has been recognized in natural and wastewater systems, the existence of the Zn basic carbonate, hydrozincite, has not been fully appreciated even though solubility data have been available. In the presence of 2 mM total inorganic carbonate, Zn^{2+} solutions below pH 8.2 were found to precipitate hydrozincite within 24 h and to contain total dissolved Zn concentrations that were comparable to those predicted from equilibrium with hydrozincite. The identity of the hydrozincite was confirmed by X-ray diffraction and elemental analyses. In the pH range 8.2–10.5, the total dissolved Zn concentrations were less than that expected from equilibrium with hydrozincite by factors of up to 3, while the precipitated solids had C:Zn ratios intermediate between those of hydrozincite and give oxide and exhibited weak hydrozincite X-ray diffraction patterns. At pHs above 10.5, zinc oxides with strong X-ray diffraction patterns were present and total dissolved Zn concentrations approached those expected for equilibrium with zinc oxide. In solutions prepared to exclude carbonate, the total dissolved zinc concentrations in all solutions were similar to those expected for equilibrium with zinc oxide. However, two solids in these "carbonate-free" solutions contained small amounts of inorganic carbonate and exhibited weak hydrozincite X-ray diffraction patterns. The presence of well-defined or poorly-crystalline hydrozincite in all 2 mM inorganic carbon solutions between pH 8–10 and its presence in two solutions prepared to exclude carbonate contamination suggest that hydrozincite is probably a common Zn solid formed in conventional precipitation processes.

PM-064

PAULSON, A.J., H.C. CURL, JR., and R.A. FEELY. Estimates of trace metal inputs from non-point sources discharged into estuaries. Marine Pollution Bulletin 20(11):549–555 (1989).

Elliott Bay and Duwamish Waterway, Washington were sampled for dissolved trace metals during a period of wet weather in January 1986. High concentrations of dissolved Cu, Zn, Pb, Cd and less elevated concentrations of dissolved Ni were found in marine waters adjacent to operating shipyards and a combined sewer overflow pipe that was discharging. Changes in the transports of dissolved trace metals, which have been deduced from trace metal-salinity plots, were attributed to emissions from anthropogenic sources. While 65% of the dissolved Cu and Zn transported from Elliott Bay were attributed to emissions from shipyards along Elliott Bay's shoreline, an additional 30% of the Zn was added by industrial areas adjacent to waterways supplying freshwater. Only 20% of the Elliott Bay dissolved Ni transport was contributed by shoreline sources. In contrast, anthropogenic sources did not increase the transport of dissolved Fe.

PM-065

PEASE, C.H., and P. TURET. Sea ice drift and deformation in the western Arctic. Oceans '89 Proceedings, Seattle, WA, September 18–21, 1989, Vol. 4: Acoustics, Arctic Studies. Marine Technology Society, IEEE Publication Number 89CH2780-5, 1276–1281 (1989).

Groups of ARGOS sea ice buoys were deployed in the Bering, Chukchi, and Beaufort seas over a decade. The pattern that emerges shows that Norton Sound and the coastal zone of the Seward Peninsula episodically produce ice that is both exported to the Arctic through Bering Strait and fed to the conveyor belt system of the southern Bering Sea. Additional major ice formation centers for the Bering system are the west coast of Alaska from the Yukon to Nunivak Island during easterly winds and the St. Lawrence Island polynya and Chukotsk Peninsula during northerly winds. Additional ice formation centers for the Chukchi system are the west coast of Alaska during easterly winds and intrusions of ice from the Beaufort coastal zone. There is a net partitioning of the drift in the Chukchi between the Alaskan Coastal Current and the broad flow out Hope Valley toward Wrangel Island. Although the vector mean drift in Bering Strait is northward, the mean is smaller than the currents at depth because of wind reversals and the interannual variability is large. Mesoscale strain was estimated for triplets of ARGOS buoy tracks in the western Arctic. On the open Bering Shelf tidal energy dominates both the velocity field (20–50%) and the components of the strain field. Also the M_4 tidal component of the ice velocity is about 45% of the amplitude of M_4, while M_4 in the ocean current is about 2%. This partial shift from semi-diurnal (12.4-hr) to 6.2-hour energy is caused by a compressional wave which propagates through the pack at both extremes of the semi-diurnal tidal oscillation. Daily gaps in the ARGOS coverage due to the distribution of satellite passes at low polar latitudes can be bridged best by using the tidal information from regional current measurements with appropriately enhanced M_4 to help generate a synthetic series, rather than least-squares or spline curve fitting techniques.

PM-066

Perillo, G.M.E., and J.W. LAVELLE. Sediment transport processes in estuaries: An introduction. Journal of Geophysical Research 94(C10), 14,287–14,288 (1989).

No abstract.

PM-067

Picaut, J., A.J. Busalacchi, M.J. MCPHADEN, and B. Camusat. Validation of the geostrophic method for estimating zonal currents at the equator from Geosat altimeter data. Journal of Geophysical Research 95(C3):3015–3024 (1990).

The applicability of satellite altimeter data for estimating zonal current variability at the equator is assessed using the meridionally differenced form of the geostrophic balance. Estimates of geostrophic zonal flow anomalies in the equatorial Pacific have been deduced from 17-day collinear altimeter data during the first year of the Geosat Exact Repeat Mission, November 1986 to November 1987. Altimeter-derived geostrophic estimates agree well with in situ zonal current variability. Comparison of low-frequency, near-surface zonal current observed from equatorial moorings at 165°E, 140°W, and 110°W yield correlations of 0.83, 0.85, and 0.51, respectively, with a mean rms difference of 23 cm s^{-1}. The geostrophic currents were calculated from all available ascending and descending Geosat tracks within ±4.5° of longitude from each mooring site. The inclusion of up to 11 ascending and descending Geosat tracks within the 9° band for every 17-day repeat effectively reduced the temporal sampling interval to 1.5 days at 165°E and 140°W. However, only ascending tracks were available at 110°W. Alongtrack sea surface heights were first smoothed using a combination of linear and nonlinear filters. The 6.8 km alongtrack spacing of the altimeter measurements provides sufficient resolution for the effective filtering of small-scale meridional noise, both instrumental and oceanic. High-frequency temporal variability, such as noise and ageostrophic motions, was suppressed with a 31-day Hanning filter. Sea level and zonal velocity solutions from a tropical Pacific numerical model were used as proxy data sets in order to estimate errors induced into the geostrophic calculation by the Geosat space-time sampling.

PM-068

Picaut, J., B. Camusat, T. Delcroix, M.J. MCPHADEN, and A.J. Busalacchi. Surface equatorial flow anomalies in the Pacific Ocean during the 1986–87 ENSO using GOESAT altimeter data. Proceedings of the Western Pacific International Meeting and Workshop on TOGA COARE, Nouméa, New Caledonia, May 24–30, 1989. ORSTOM, 301–309 (1989).

Estimates of surface geostrophic zonal flow in the equatorial Pacific are deduced from the 17-day exact repeat orbit GEOSAT measurements for the period November 1986–November 1987. This period coincides with the height of the 1986–87 ENSO. Along-track altimeter height anomalies are first smoothed using a combination of linear and nonlinear filters. By combining several tracks in the zonal direction and filtering in time, we are able to obtain low frequency sea surface height at any point of the tropical Pacific. Currents are calculated from the differentiated form of the meridional momentum equation at the equator and from the classical first derivative of the meridional pressure field away from the equator. Comparisons of low frequency near-surface zonal current directly measured from equatorial moorings at 165°E, 140°W and 110°W yield a correlation of 0.83, 0.84, and 0.50 respectively with a mean rms difference of 0.23 m s^{-1}. Sea level and zonal velocity solutions from a tropical Pacific numerical model are used as proxy data sets in order to quantify errors induced to quantify the geostrophic calculation by the GEOSAT space-time sampling. In December 1986, a downwelling equatorial Kelvin wave is generated in the western Pacific and shows up, near the forcing area, as an intense local 1 m s^{-1} eastward equatorial surface flow anomaly. This Kelvin wave propagates into the eastern equatorial Pacific with a phase speed of about 2.5 m s^{-1} and is associated with eastward equatorial current anomalies of 0.3–0.5 m s^{-1}. In February 1987, an upwelling equatorial Kelvin wave is excited near the date line and propagates eastward. This wave, characterized by a westward flow anomaly of 0.3–0.8 m s^{-1}, reaches the eastern Pacific boundary in March 1987 where it forces apparently an upwelling first meridional mode equatorial Rossby wave. This Rossby wave propagates westward in the ocean interior at about 0.8 m s^{-1} as a patch of equatorially trapped eastward flow (0.6–0.8 m s^{-1} maximum) flanked, in both hemispheres, by 0.2–0.4 m s^{-1} westward flow anomalies which decreased the South Equatorial Current and the North and South Equatorial Countercurrents. The equatorial Rossby wave propagation could be traced sequentially through the eastern, central and western Pacific from April to September 1987. Thus GEOSAT altimeter data indicate that equatorial Kelvin waves and possible eastern reflection as equatorial Rossby waves are an important component of basin scale surface current variability during the 1986–87 ENSO.

PM-069

PROCTOR, P.D. Fisheries-Oceanography Coordinated Investigations—Field Operations 1988. NOAA DR ERL PMEL-25 (NTIS PB90-159088), 69 pp. (1989).

No abstract.

PM-070

QUINN, P.K., T.S. BATES, J.E. JOHNSON, D.S. Covert, and R.J. Charlson. Interactions between the sulfur and reduced nitrogen cycles over the central Pacific Ocean. Journal of Geophysical Research 95(D10):16,405–16,416 (1990).

In April and May of 1988 along 170°W from 53°N to 14°S, simultaneous concentration measurements were made of the major components of the sulfur and reduced nitrogen cycles. The species measured included seawater dimethylsulfide, DMS (s), and total ammonia, NH_3 (s,tot) = NH_3 (s) + NH_4^+ (s); atmospheric gas phase DMS (g), NH_3 (g), and SO_2 (g); and atmospheric particulate phase NH_4^+ (p), non-seasalt sulfate, nss $SO_4^=$ (p), and methanesulfonate, MSA (p). Based on isentropic calculated back trajectories at 1000, 950, 850, and 700 mbar arrival heights, three apparent air mass regimes were encountered; one from 50°N to 30°N which recently had been in contact with Asia, one from 29°N to 15°N which had passed over Hawaii during a volcanic eruption several days earlier, and one from 14°N to 11°S which was the most representative of remote marine air. Changes in the relative concentrations of the atmospheric S and NH_3 species reflected the origin of the air masses sampled. The NH_3 (g) concentrations were low over the entire region studied, indicating that the lifetime of NH_3 in the marine boundary layer is on the order of hours. These low NH_3 concentrations led to only partially neutralized sulfate aerosol particles. The mean NH_4^+ (p) to nss $SO_4^=$ (p) molar ratio was 1.3 ± 0.71. The highest ratios were found in continentally influenced air masses where the NH_4^+ (p) was most likely of continental origin and in remote marine air masses with an absence of continentally derived nss $SO_4^=$ (p). The lowest ratios found were a result of high nss $SO_4^=$ (p) concentrations in air masses influenced by the Hawaiian volcanic plume. Seawater concentrations of DMS (s) and NH_3 (s,tot) were lowest in the North Pacific central gyre and highest in the northern latitudes and near and south of the equator.

PM-071

REED, R.K., L.S. Incze, and J.D. SCHUMACHER. Estimation of the effects of flow on dispersion of larval pollock, *Theragra chalcogramma*, in Shelikof Strait, Alaska. Effects of ocean variability on recruitment and an evaluation of parameters used in stock assessment models, R.J. Beamish and G.A. McFarlane (eds.), Canadian Special Publication of Fisheries and Aquatic Sciences 108, 239–246 (1989).

The focus of this work is to examine the effects of oceanic motions on the larvae of walleye pollock, *Theragra chalcogramma*, in Shelikof Strait, Alaska. A baroclinic coastal current flows southwestward through Shelikof Strait with typical peak speeds of 20 cm s^{-1}. Data from current moorings were used to derive eddy diffusivities and horizontal divergence (typical estimates were 5×10^6 cm^2 s^{-1} and -1.5×10^{-6} s^{-1}, respectively). The effects of horizontal advection, divergence, and turbulent diffusion on changing concentration of larvae

with time were estimated. The estimates suggest that all factors may be important. Finally, changes which could result from physical effects were compared with observed changes in abundance and distribution to estimate larval mortality.

PM-072

REED, R.K., and P.J. STABENO. Circulation and property distributions in the central Bering Sea, Spring 1988. NOAA TR ERL 439-PMEL 39 (NTIS PB90-155847), 13 pp. (1989).

Data from a synoptic CTD survey in the central Bering Sea in winter 1988 are used to examine circulation and property distributions. A coherent, cyclonic circulation existed over much of the region. Geostrophic flow as great as 40 cm s^{-1} was present over the continental slope; another branch of relatively strong flow was situated over the shelf near a surface salinity front. The characteristic subsurface temperature minimum and maximum were both found in less dense water than in previous observations. Six satellite-tracked drifting buoys were also deployed. Their paths were in general agreement with the geostrophic flow, but some small eddies were revealed by the drifters that were not detected by the CTD data.

PM-073

REED, R.K., and P.J. STABENO. Recent observations of variability in the path and vertical structure of the Alaskan Stream. Journal of Physical Oceanography 19(10):1634–1642 (1989).

Current records were recently obtained from two sites on the continental slope southwest of Kodiak Island. At the inshore site (10-month record), flow mainly resembled the weak shelf-break flow typical of the Gulf of Alaska. Except for two periods, each of ~3 months duration, the offshore site (31-month record) was in the path of the Alaskan Stream. During the Alaskan Stream segments, flow characteristics (low eddy energy, high vertical coherence, and high stability) were similar to those in the stream at other locations. When the stream was absent from the offshore site, it made a seaward excursion of ~50 km as evidenced by satellite-tracked drifters. The cause of this migration is unclear. During a period of ~6 months, a subsurface velocity maximum was measured at 165 m. Flow near 1000 m was very weak for almost two years; geostrophic flow estimates, however, suggest this is a rare situation.

PM-074

Savage, D.S. Fisheries-Oceanography Coordinated Investigations—Field Operations 1989. NOAA DR ERL PMEL-26 (NTIS PB90-208448), 68 pp. (1990).

No abstract.

PM-075

SCHUMACHER, J.D., and A.W. Kendall, Jr. Fisheries Oceanography Coordinated Investigations (FOCI): Walleye pollock recruitment in the western Gulf of Alaska. Proceedings of the Gulf of Alaska, Cook Inlet, and North Aleutian Basin Information Update Meeting, Anchorage, AK. OCSEAP/MMS, 39–47 (1989).

No abstract.

PM-076

SCHUMACHER, J.D., P.J. STABENO, and A.T. ROACH. Volume transport in the Alaska Coastal Current. Continental Shelf Research 9(12):1071–1083 (1989).

Nine moorings were deployed in three sections in the Shelikof Strait/Semidi Islands region of the Alaskan continental shelf during the period of August 1984 to July 1985. Analysis of the resulting current and bottom pressure data, together with surface wind, provides a new understanding of transport in the Alaska Coastal Current. Using current observations, mean volume transport through the Shelikof sea valley was computed to be 0.85×10^6 m^3 s^{-1}, which is in good agreement with estimates of transport obtained from hydrographic data. Approximately 75% of this flux flowed seaward through the Shelikof sea valley, with the remainder flowing along the Alaska Peninsula. Data showed the expected increase of volume transport concomitant with maximum freshwater discharge in autumn. The greatest monthly mean transport, however, occurred in winter and was related to wind forcing. On time intervals of days, fluctuations in transport were often large (up to 3.0×10^6 m^3 s^{-1}), and generally geostrophic ($r = 0.79$). Some of these fluctuations resulted from convergence of flow caused by the complex interaction of storms with orography. Approximately half of the fluctuations in volume transport were accounted for by the alongshore wind.

PM-077

Smith, S.D., R.D. Muench, and C.H. PEASE. Polynyas and leads: An overview of physical processes and environment. Journal of Geophysical Research, 95(C6):9461–9479 (1990).

Polynyas and leads are openings in pack ice due to divergences in ice drift and to local melting. They are the vents and windows to the polar oceans. In winter they are a major source of brine during freezing and a locus for gas exchange. Large sensible heat fluxes, together with evaporation and longwave radiation from a very small percentage of open water and thin ice, dominate regional heat budgets. In summer, solar radiation is absorbed by open water but is reflected from snow-covered pack ice. Experiments and models describing these processes are reviewed.

Addendum

PM-078

BERNARD, E.N. Early warning system for tsunamis is tested successfully in Chile. Water Research Journal, September 1989, 66–69 (1989).

Throughout history, natural disasters have killed, injured, and displaced people of every nation on the globe. Recently, a local system that includes emergency planning, hazard assessment, and rapid warning via satellite communication links has been successfully tested in tsunami-prone Chile. Rapid-onset natural hazards, such as earthquakes, landslides, tsunamis, hurricanes, tornadoes, floods, volcanic eruptions, and wildfires, have claimed more than 2.8 million lives worldwide in the past 20 years and have adversely affected 820 million people. The world's vulnerability and the social and economic cost of these hazards will only increase in the future because of population growth and urban concentration, increased capital investment coupled with new technologies, the existence of vulnerable critical facilities and fragile lifelines, and increasing interdependence of local, national, and international communities.

PM-079

BERNARD, E.N. Early warning system for tsunamis is tested successfully in Chile. Earth in Space 1(9):7–10 (1989).

Throughout history, natural disasters have killed, injured, and displaced people of every nation on the globe. Recently, a local system that includes emergency planning, hazard assessment, and rapid warning via satellite communication links has been successfully tested in tsunami-prone Chile. Rapid-onset natural hazards, such as earthquakes, landslides, tsunamis, hurricanes, tornadoes, floods, volcanic eruptions, and wildfires, have claimed more than 2.8 million lives worldwide in the past 20 years and have adversely affected 820 million people. The world's vulnerability and the social and economic cost of these hazards will only increase in the future because of population growth and urban concentration, increased capital investment coupled with new technologies, the existence of vulnerable critical facilities and fragile lifelines, and increasing interdependence of local, national, and international communities.

PM-080

FREITAG, H.P., M.J. MCPHADEN, and A.J. SHEPHERD. Real-time surface currents from moored buoys. Proceedings, 1989 North American Argos Users Conference and Exhibit, San Diego, CA, May 15–17, 1989. Service Argos Inc., Landover, MD, 85–100 (1989).

Real-time near surface current and temperature are transmitted via Argos from taut-line moorings in the equatorial Pacific. The moorings are part of EPOCS and TOGA programs to study interannual variability in the wind, current, and temperature fields related to the El Niño/Southern Oscillation phenomenon. An EG&G Vector Measuring Current Meter at 8 m depth transfers serial data at two-hour intervals to an Argos transmitter on a surface buoy via a 3-wire conducting cable and interface. Four two-hour average data values are included in each Argos transmission. This sample rate assures complete daily coverage on the equator. The system is presently incorporated on moorings at 0°, 110°W, 0°, 140°W, and 0°, 165°E which are replaced at 6-month intervals. An independent instrument package on the buoy transmits vector-averaged winds, air and sea-surface temperature. These current meter moorings are a part of a larger network of moorings which cover the equatorial Pacific from 165°E to 110°W.

PM-081

Napolitano, D.J., J.F. Vesecky, F. GONZALEZ, and S. Petscherych. SAR measurements of ocean waves and other surface phenomena during the GOASEX Experiment. Proceedings of the 1989 International Geoscience and Remote Sensing Symposium, Vancouver, B.C., Canada, July 10–14, 1989, 2331–2334 (1989).

Synthetic aperture radar (SAR) is an important remote sensing tool for observation of the ocean over a large range of scales from 10's of meters to 1000's of km. Unique properties of SAR include self-illumination and cloud penetration because of the microwave frequencies employed. To evaluate SAR for observing the ocean surface, the SEASAT satellite was launched in 1978. To validate SAR ocean measurements, the Gulf of Alaska Experiment (GOASEX) was set up to provide measurements of the ocean surface and atmosphere within a region imaged by SAR. This data set is important because it contains a significant portion of the surface truth data collected during the SEASAT mission. With this data set, direct comparison between SAR and buoy ocean measurements can be made since the surface truth data was obtained *in situ* at the SEASAT overpass time. In this paper we compare SAR and surface observations of ocean waves. Further,

we assess several models for SAR imaging of the ocean developed by Alpers, Harger, and Rotheram and Macklin. Lastly, we utilize the SAR for examining windrows on the ocean surface.

PM-082

WALTER, B.A. A study of the planetary boundary layer over the polynya downwind of St. Lawrence Island in the Bering Sea using aircraft data. Boundary-Layer Meteorology 48:255–282 (1989).

Turbulence data collected with the gust probe system on the NOAA P-3 aircraft over the polynya downwind of St. Lawrence Island in the Bering Sea are used to study the fluxes of heat, momentum, and moisture from the polynya. The data also allow study of the effect of the topography of St. Lawrence Island on the atmospheric boundary-layer flow over the polynya and ultimately on ice production in the polynya. Two cases are studied: one (Feb. 15, 1982) where the topographic effects are minimal and the other (Feb. 18, 1983) where the topographic effects are dominant. Calculation of the surface drag coefficient, C_D, for the Feb. 15, 1982 case over young grey/white ice gave a value of 1.2×10^{-3}, which is in close agreement with previous results. The value of the drag coefficient for the grey/white ice regime on Feb. 18, 1983, where the upstream topography on St. Lawrence Island had an important influence on the flow over the polynya, was 3.2×10^{-3}. It was determined that this higher value was related to the more efficient mixing of momentum downward by turbulent eddies generated by flow over and around the topography. The area-averaged heat transfer coefficient, C_H, over the polynya was on the order of 1.1×10^{-3} for both days, but there were large variations in heat flux across the polynya due to variations in the flow caused by the topography. Conditional sampling techniques applied to the turbulence data showed that the fractional areas occupied by updrafts and downdrafts were 28% and 36%, respectively, and that these results were within the range of values found in previous studies for over-land and over-ocean conditions.

SPACE ENVIRONMENT LABORATORY

SE-001

ALLEN, J., H. SAUER, L. Frank, and P. Reiff, Effects of the March 1989 solar activity. EOS 70(46): 1479–1488 (1989).

No abstract.

SE-002

Barth, C.A., W.K. Tobiska, G.J. Rottman, G.J., and O.R. White, Comparison of 10.7 cm radio flux with SME solar lyman alpha flux. Geophysical Research Letters 17(5): 571–574 (1990).

Measurements of the solar Lyman alpha flux that were made over a seven-and-one-half-year period between October 11, 1981, and April 13, 1989, have been compared with ground-based measurements of the solar 10.7 cm radio flux made over the same time period. There is a long-term correlation between these two measures of solar flux during the declining part of the solar cycle. During the solar minimum period, there is only a poor correlation between the two solar fluxes because the 10.7 cm radio flux reaches a minimum of 65 x 10^{-22} W m^{-2} Hz^{-1} and does not vary below this value while the Lyman alpha flux continues to decline and show long-term and short-term variations. During the early ascending phase of the new solar cycle, there is again a correlation between the two fluxes, although the constant of proportionality between the two is different from the constant during the declining phase of the previous solar cycle. Somewhat later, during the period November 25, 1988–April 13, 1989 (last period when observations of Lyman alpha were made), a medium-term correlation exists and the proportionality of the two indices is once again similar to what it was during the declining phase of the previous solar cycle. A study of the correlation of the 10.7 cm flux with the Lyman alpha for a 999-day period during the declining phase showed that for the short-term (27-day) variation there is a correlation between the two fluxes but the proportionality between them varies from one solar rotation to the next. The conclusion is that the solar 10.7 cm radio flux is not a useful index for the prediction of solar Lyman alpha flux for the short-term, 27-day variations.

SE-003

BORNMANN, P.L., Limits to derived flare properties using estimates for the background fluxes: Examples from GOES. The Astrophysical Journal 356: 733–742 (1990).

Most methods for deriving the temperature and emission measure during solar and stellar flares require subtraction of the correct amount of background, nonflare flux. If no subtraction is done, one implicitly averages over all emitting sources within the field of view, which can give derived properties that differ from the properties of the flare itself. At the other extreme, subtraction of the entire preflare flux avoids averaging over other sources but implicitly assumes that the flare plasma did not emit outside of flaring times. This, then, requires that either the temperature or the emission measure of the flare plasma was zero before and after the flare, which is not expected. A new method is presented for deriving the limits to the background fluxes that should be subtracted from the total flux to give the flare flux. This method is based on the assumption that the temperature, emission measure, and fluxes should all increase at the start of the flare. In addition, the flaring active region is assumed to be hotter than the average of all background sources. Solar soft x-ray fluxes observed by the disk-integrating x-ray sensors on the GOES spacecraft during the 1986 February 3 and 1987 October 22 flares are used to demonstrate this method. Results from this method show that the flare properties do not always lie between those derived by either using or subtracting the entire preflare flux. The addition of a third limit, found by subtracting the long-wavelength and using the short-wavelength preflare fluxes, is necessary to bound the flare properties.

SE-004

BORNMANN, P.L., The Sun as a flare star: X-ray spatial and plasma properties derived from a solar eclipse observed by GOES. In Solar and Stellar Flares, IAU Colloquium No. 104, 15–19 August 1988, Stanford University, California, B.M. Haisch and M. Rodono (eds.), pp. 157–160 (1989).

The size, location, and flux of four solar soft x-ray sources, including a flare, were derived from the disk-integrating GOES X-Ray Sensors during a solar eclipse. The fluxes were used to derive the temperatures and emission measures of these sources. If an incorrect amount of flux is attributed to the flare source, then the evolution of these derived plasma properties seems unphysical.

SE-005

BORNMANN, P.L., and L.D. MATHESON, Solar flare plasma properties derived from the disk-integrating GOES x-ray sensors during an eclipse. Astronomy and Astrophysics 231: 525–535 (1990).

During a small flare on 1987 October 22 at ~1100 UT one of the two identical GOES satellites experienced a partial solar eclipse caused by the Moon. Data from the disk-integrating GOES x-ray sensors are analyzed to extract the locations, sizes, and fluxes of the flare and three additional x-ray sources. The properties of these x-ray sources are compared with observations of optical coronal lines and EUV rocket data. The temperatures and emission measures are derived for each of the x-ray sources, including the flare. Implicit

assumptions involved in assuming that the flare flux is either the total solar flux or just the increase above the quiescent level are examined. These assumptions produced unexpected results of either temperatures that decreased at flare onset or emission measures that decreased at the start and then increased at the end of the flare. These results are caused by either averaging over multiple sources or assuming that the flare plasma did not radiate outside of flare times. Behind-the-solar limb effect and contamination from magnetospheric electrons are considered, and found to be insufficient to cause the slight discrepancies in the fluxes recorded at the two GOES satellites.

SE-006

Bouwer, S.D., J. Pap, and R.F. DONNELLY, Dynamic power spectral analysis of solar measurements from photospheric, chromospheric, and coronal sources. In Climate Impact of Solar Variability, Proceedings of a conference held at NASA Goddard Space Flight Center, Greenbelt, MD, April 24-27, 1990, NASA Conference Publication 3086, K.H. Schatten and A. Arking (eds.), NASA, Greenbelt, MD, pp. 125-132 (1990).

An important aspect in the power spectral analysis of solar variability is the quasistationary and quasiperiodic nature of solar periodicities. In other words, the frequency, phase, and amplitude of solar periodicities vary on time scales ranging from active region lifetimes to solar cycle time scales. In this study we employ a dynamic, or running, power spectral density analysis to determine many periodicities and their time-varying nature in the projected area of active sunspot groups (S_{act}), the SMM/ACRIM total solar irradiance (S), the Nimbus-7 MgII center-to-wing ratio ($R(\mathrm{MgII}_{c/w})$), the Ottawa 10.7 cm flux ($F_{10.7}$), and the GOES background x-ray flux (X_b) for the maximum, descending, and minimum portions of solar cycle 21 (i.e., 1980-1986). This technique dramatically illustrates several previously unrecognized periodicities. For example, a relatively stable period at about 51 days has been found in those indices which are related to emerging magnetic fields. The majority of solar periodicities, particularly around 27, 150, and 300 days, are quasiperiodic because they vary in amplitude and frequency throughout the solar cycle. Finally, it is shown that there are clear differences between the power spectral densities of solar measurements from photospheric, chromospheric, and coronal sources.

SE-007

Brown, T.J., J.A. Flueck, J. JOSELYN, and J.J. STEPHENSON, Evaluation of the 10.7 cm solar flux using contingency tables and visual displays. In Proceedings, 11th Conference on Probability and Statistics, October 1-5, 1989, Monterey, CA, American Meteorological Society, Boston, MA, pp. 315-317 (1989).

No abstract.

SE-008

Cuperman, S., L. Ofman, and M. DRYER, Thermally conductive magnetohydrodynamic flows in helmet-streamer coronal structures. The Astrophysical Journal 350: 846-855 (1989).

The behavior of thermally conductive plasma flows in helmet-streamer coronal structures is investigated within the framework of the axisymmetric ($\partial / \partial \phi = 0$) nonrotating ($\Omega = 0$) one-fluid MHD model. Continuous subsonic-supersonic solutions satisfying observed boundary conditions at the Sun as well as the vanishing of the temperature at infinity are obtained and presented. Special attention is paid to the combined effects of conductive flow (and corresponding thermal force) and rapidly diverging magnetic field on the critical points. In this, the heliocentric distance of the neutral point determining the separation between closed and open field lines (cusp) is treated as a free parameter. These thermally conductive solutions are contrasted with those provided by corresponding isothermal models.

SE-009

DAVIES, K., Ionospheric Radio, IEE Electromagnetic Waves Series 31, Peter Peregrinus, Ltd., London, 580 pp. (1990).

No abstract.

SE-010

DONNELLY, R.F., Solar UV temporal variations during solar cycle 22 and the twentieth century. In Climate Impact of Solar Variability, Proceedings of a conference held at NASA Goddard Space Flight Center, Greenbelt, MD, April 24-27, 1990, NASA Conference Publication 3086, K.H. Schatten and A. Arking (eds.), NASA, Greenbelt, MD, pp. 328-335 (1990).

Solar ultraviolet measurements of the Mg II core-to-wing ratio from the NOAA9 satellite show a fast rise for solar cycle 22 from the minimum in September 1986. The high values in late 1989 are comparable to the maximum values for cycle 21. Estimates of earlier solar UV variations are made back to 1947 using a combination of the 10 cm solar radio flux (F10) and the sunspot blocking function. The latter is interpreted to partially remove the gyroresonance component from F10, which is not present in the UV flux.

SE-011

DONNELLY, R.F., Solar x-ray, EUV and UV flux. In Atmospheric Density and Aerodynamic Drag Models for Air Force Operations, Proceedings of a Workshop held at AFGL, 20-22 October 1987 (F.A. Marcos, ed.), GL-TR-90-0033(II), ERP No. 1053, pp. 8-3 - 8-6 (1990).

No abstract.

SE-012

DONNELLY, R.F., and J. BARRETT, Analysis of SBUV2 measurements of solar UV irradiance variations. In NOAA-9 Solar Backscatter Ultraviolet (SBUV/2) Instrument and Derived Ozone Data: A Status Report On a Review on January 29, 1990, NOAA Tech. Report NESDIS SRL ORA, Washington, DC, pp. 12-1 to 12-5 (1990).

The NOAA-9 and NOAA-11 SBUV2 monitoring instruments in the discrete wavelength mode are discussed for the core-to-wing ratio of the solar Mg II h & k lines near 280 nm. A new ratio, similar to Heath and Schlesinger's (1986) ratio for NIMBUS7, has been adopted for NOAA-9 and NOAA-11 to avoid drift problems associated with the low-amplification third intensity range in the photomultiplier cathode circuit. This new ratio provides an excellent ratio of solar signal to instrument noise for the NOAA-9 & 11 because of SBUV2's superb wavelength repeatability. Recommendations for the SBUV2 instruments that have not yet flown and for future operation of the SBUV2 monitors are presented based on our experience with NOAA-9 and NOAA-11.

SE-013

DRYER, M., and Z.K. SMITH, Multi-spacecraft testing of the time-dependent interplanetary MHD models for operational forecasting of geomagnetic storms. Earth, Moon, and Planets 45: 161-173 (1989).

An MHD 2½-D, time-dependent model is used, together with observations of six solar flares during 3-7 February 1986, to demonstrate global, large-scale, compound disturbances in the solar wind over a wide range of heliolongitudes. This scenario is one that is likely to occur many times during the cruise, possibly even encounter, phases of the Multi-Comet Mission. It is suggested that a model such as this one should be tested with multi-spacecraft data (such as the MCM and Earth-based probes) with several goals in view: (1) utility of the model for operational real-time forecasting of geomagnetic storms, and (2) scientific interpretation of certain forms of cometary activities and their possible association with solar-generated activity.

SE-014

Fairfield, D.H., D.N. Baker, J.D. Craven, R.C. Elphic, F.F. Fennell, L.A. Frank, I.G. Richardson, H.J. Singer, J.A. Slavin, B.T. Tsurutani, and R.D. ZWICKL, Substorms, plasmoids, flux ropes, and magnetotail flux loss on March 25, 1983: CDAW 8. Journal of Geophysical Research 94: 15,135-15,152 (1989).

During a 9-hour period following a storm sudden commencement on March 25, 1983, six spacecraft near geosynchronous orbit, one over the pole, and three in the magnetotail monitored a complex sequence of magnetospheric variations. Magnetic field compressions associated with the sudden commencement were seen first by the near-Earth spacecraft and subsequently by the three downtail spacecraft with increasing time delays that were consistent with the tailward movement of an interplanetary-shock-associated pressure enhancement. Ground magnetograms and synchronous orbit data are used to identify seven substorm intensifications during this geomagnetically active period. Six of these intensifications are clearly associated with tail lobe field decreases ~18 R_E behind the Earth. Four of these intensifications are followed by both B_z field increases in the tail lobes at ~18 and ~30 R_E and by the subsequent observation of rapidly flowing plasma sheet plasma at ISEE 3 ~110 R_E down the tail. During two substorms where DE 1 was optically observing the auroral oval, the area of the polar cap was observed to decrease as the tail lobe field decreased at 18 R_E. All these observations are consistent with the substorm-associated release of a plasmoid at a neutral line near 20 R_E; however, the classical north-south variation of the plasma sheet magnetic field thought to be characteristic of the passage of a plasmoid in the deep tail was not seen in every case.

SE-015

Feldman, W., M. Mellott, B. Tsurutani, B. Goldstein, R. Farquhar, J. Anderson, D. Bohlin, L Burlaga, G. Gloeckler, J. Harvey, T. Holzer, V. Jones, P. Kellogg, S.M. Krimigis, M. Kundu, A. Lazarus, E. Parker, R. Rosner, G. Rottman, J. Slavin, S. Suess, R. Woo, and R. ZWICKL. Solar Probe: Scientific Rationale and Mission Concept. JPL D-6769, Jet Propulsion Laboratory, California Institute of Technology, 113 pp. (1989).

No abstract.

SE-016

GARCIA, H.A., Evidence for solar-cycle evolution of north-south flare asymmetry during cycles 20 and 21. Solar Physics 127: 185-197 (1990).

The record of flare incidence from January 1969 to October 1988 indicates that the north-south (N-S) distribution of large flares is periodic and approximately in phase with the 11-year sunspot cycle. These data are based on observations of the whole-disk Sun on continuum soft x-rays which commenced in early 1969 and have proceeded without interruption to the present time. The pattern of occurrence, observed for slightly less than two sunspot cycles, is that large flares concentrate in north heliographic latitudes soon after solar minimum and then migrate gradually southward as the cycle progresses. By the end of the cycle, most large flares occur in the south. The degree of N-S asymmetry apparently is a function of the intensity of the flare; the most intense flares show the largest amount of N-S asymmetry. The data suggest that sunspots and flares may be driven by distinctly different excitation mechanisms arising at different levels in the convection zone. This conjecture is supported by recent work of Bai (1987, 1988), who has discovered that the superactive regions producing the majority of flares rotate at a speed substantially different from the Carrington rate, which is based primarily on the observed motion of sunspots.

SE-017

Han, S.M., Three-Dimensional MHD Models of Solar-Generated Disturbances in the Interplanetary Medium. Final Report, NOAA Contract 40RAN8B7172, Tennessee Technological University, Cookeville, Tennessee, 31 pp. (1990).

No abstract.

SE-018

Harrison, R.A., E. HILDNER, A.J. Hundhausen, D.G. Sime, and G.M. Simnett, The launch of solar coronal mass ejections: Results from the coronal mass ejection onset program. Journal of Geophysical Research 95(A2): 917-937 (1990).

We describe a set of solar coronal mass ejection (CME) events where coincident data sets from both X ray and white light instruments have been made available through deliberate planning. Using these we have been able to put tight limits on possible descriptions of the typical sequence of events, and these we relate to interpretations of models involving flares and CMEs. Our findings confirm recent suggestions that CME onsets precede any related flare activity and that the associated flaring commonly lies to one side of the CME span. The CME launch appears to be associated with minor X ray (flare precursor) activity. Although this scenario has been previously discussed (see Harrison, 1986, and references therein), the abundance of flare and CME models which are not compatible with this picture demands that confirmation be sought using programs such as this.

SE-019

HILDNER, E., Solar flares--physics and prediction. In Astrophysics From The Moon, Annapolis, MD, 1990, AIP Conference Proceedings 207, M.J. Mumma and H.J. Smith (eds.), American Institute of Physics, New York, pp. 131-138 (1990).

The study of solar flares will be extremely important for a lunar base. Not only are solar flares interesting from a scientific point of view, but, perhaps even more importantly, the energetic particles from solar flares will bombard the lunar base and at times make it extremely hazardous, even fatal, to astronauts working unprotected on the lunar surface. Of course, the two motivations are coupled; with better understanding of solar flare physics, predictions of solar flares and their consequences can be improved. To reduce telecommunications that would otherwise be necessary between a lunar base and the Earth, there is value in monitoring the Sun from the lunar base and analyzing the data to make predictions on-site.

SE-020

JOSELYN, J.A., Case study of the great geomagnetic storm of 13 March 1989 (Proceedings, AAS/AIAA Astrodynamics Specialist Conference, August 7-10, 1989, Stowe, VT). Advances in the Astronautical Sciences 71: 745-761, 1990.

No abstract.

SE-021

JOSELYN, J.A., and E.C. Whipple, Effects of the space environment on space science. American Scientist, 78: 126-133.

No abstract.

SE–022

Kikuchi, T., and D.S. EVANS. Energetic electrons observed by NOAA–6 over Japan (L = 1.3) at the time of geomagnetic storm on February 8–9, 1986. Proceedings of the Research Institute of Atmospherics, Nagoya University, Vol. 36, No. 2, pp. 137–149 (1989).

Unusual enhancements of electron fluxes (E > 30, > 100, and > 300 keV) were observed when the polar orbiting NOAA–6 satellite passed over Japan (L = 1.3) at the time of the large geomagnetic disturbance in the pre-midnight sector (2040 MLT) as evidenced by the cosmic noise absorption in Syowa, Antarctica, and enhancement of proton flux (0.8–4.0 MeV) detected by the geosynchronous meteorological satellite, GMS. The intensification of the sky wave strength of the LF standard signal (f = 40 kHz) observed on the path below the satellite orbit may be ionospheric effects of the enhancement of energetic electron flux.

SE–023

Knipp, D.J., A.D. Richmond, G. Crowley, O. de la Beaujardiere, E. Friis-Christensen, D.S. EVANS, J.C. Foster, I.W. McCrea, F.J. Rich, and J.A. Waldock, Electrodynamic patterns for September 19, 1984. Journal of Geophysical Research 94: 16,913–16,923 (1989).

Variations of the northern high-latitude ionospheric convection pattern are estimated from combined ground-based and satellite-based measurements for the disturbed day of September 19, 1984, during the Equinox Transition Study (ETS) campaign period. The electric potential distribution is determined from the Assimilative Mapping of Ionospheric Electrodynamics (AMIE) procedure of Richard and Kamide (1988) on the basis of available electric field, conductance, and magnetic perturbation observations. As an improvement over previous data inversion studies of high-latitude electrodynamics, we have incorporated satellite measurements of precipitating particles to help determine variations of the conductances in the auroral oval. these measurements are found to cause substantial modifications to the initial empirical conductance model. A large substorm commenced about 0920 UT and peaked about 1050 UT, followed by smaller substorms starting about 1430 UT and 1800 UT. The polar-cap potential drop varied between about 30 kV and 160 kV during the day, and the integrated Joule heating over the northern polar region varied between 3×10^9 W and 8.6×10^{11} W. During the substorms the derived convection potential was considerably enhanced and distorted with respect to the empirical model of Foster et al. (1986). Strong eastward convection in the midnight sector of the auroral oval during the first large substorm was associated with a marked westward rotation of the two-cell convection pattern at the peak of the substorm. These variations can be expected to have influenced significantly the dynamics of the high-latitude ionosphere and thermosphere during the ETS period.

SE–024

KUNCHES, J.M., and J.W.. HIRMAN, Predicted solar flare activity for the 1990s: Possible effects on navigation systems. Navigation: Journal of The Institute of Navigation 37(2): 169–179 (1990).

The current solar cycle, which began in September 1986, may prove to be the highest ever, as measured by sunspot numbers and radio flux. The cycle's frequent and strong solar flare activity can be illustrated by the March 1989 episode, which caused many problems for navigation systems. Flares and the geomagnetic storms that sometimes accompany them can disrupt low-frequency systems such as Loran–C, as well as the satellite-borne GPS. Although the maximum of the solar cycle is expected during the first quarter of 1990, flare activity is likely to persist at high levels for a few years to follow. Geomagnetic activity may occur at any time in the cycle, and thus geomagnetic disruptions are possible at any point in the 1990s.

SE–025

KUNCHES, J.M., and J.W.. HIRMAN, Solar flare activity and predictions for the 1990s. In Proceedings of the Eighteenth Annual Technical Symposium of The Wild Goose Association, October 29–November 1, 1989, Hyannis, MA, The Wild Goose Association, Bedford, MA, pp. 3–10 (1990).

This solar cycle, which began in September of 1986, may prove to be the highest ever in terms of sunspot numbers and radio flux. Solar flare activity has also been elevated, with the episode in March 1989 being the most spectacular. Solar flares and their effects disrupt a variety of man-made technologies including low-frequency systems such as LORAN, (LO)ng (RA)nge (N)avigation. Although the maximum of the solar cycle is expected during the first quarter of 1990, flare activity is likely to linger at high levels for a few years to follow. Geomagnetic activity, which also affects LORAN, can occur at any time in the solar cycle, and geomagnetic disruptions are possible at any point in the 1990s.

SE–026

Kundu, M., N. Gopalswamy, S. White, P. Cargill, E.J. Schmahl, and E. HILDNER, The radio signatures of a slow coronal mass ejection: Electron acceleration at slow-mode shocks? The Astrophysical Journal 347: 505–513 (1989).

Using two-dimensional radio imaging observations along with simultaneously obtained coronagraph observations, we study the evolution of a coronal mass ejection (CME) event observed on 1985 February 17. In contrast to the results obtained during the Skylab and early Solar Maximum Mission (SMM) period, this event shows that a slow CME (i.e., ~ 200 km s^{-1}) can be associated with type II

and type IV radio bursts. We discuss the implications of the spatial association of the radio bursts with the CME. The type II burst shows very fast nonradial motion; it appears to be associated with a flare behind the limb. We argue that the CME is due to an instability of the large-scale magnetic field in a helmet streamer and the radio bursts are some of the responses to this instability. The new feature of this event is the clear association of the moving type IV burst with a CME traveling slower than the coronal Alfvén speed. Such a CME can drive a slow-mode shock. We discuss the structure of such slow shocks and show that shock drift and diffuse acceleration are ineffective. Instead we propose an acceleration mechanism involving current-driven lower hybrid waves, which can operate at both fast and slow shocks, as the source of the energetic electrons producing the moving type IV burst.

SE–027

LEWIS, L.D., and R.N. GRUBB, The IPS Data Acquisition and Communication System. NOAA Tech. Memo ERL SEL–91, 71 pp. (1990).

No abstract.

SE–028

London, J., J. Pap, and G. Rottman, Observed solar near UV variability: A contribution to variation of the solar constant. In Middle Atmosphere Program, V. 29, J. Lastovicka, T. Miles, and A. O'Neill (eds.), pp. 9–12 (1989).

Continuous measurements of the solar UV have been made by an instrument on the Solar Mesosphere Explorer (SME) since October 1981. The results for the wavelength interval 200–300 nm show an irradiance decrease to a minimum in early 1987 and a subsequent increase to mid-April 1989. The observed UV changes during part of solar cycles 21–22 represent approximately 35 percent (during the decreasing phase) and 25 percent (during the increasing phase) of the observed variations of the solar constant for the same time period as the SME measurements.

SE–029

Maeda, S., T.J. Fuller-Rowell, and D.S. EVANS, Zonally averaged dynamical and compositional response of the thermosphere to auroral activity during September 18–24, 1984. Journal of Geophysical Research 94: 16,969–16,883 (1989).

A time-dependent calculation has been performed to study the dynamical and compositional response of the thermosphere to auroral disturbances. The heat and momentum inputs associated with auroral activity were estimated by using an empirical model constructed from two data bases: the precipitating particles monitored by the TIROS/NOAA satellites and the ionospheric convection electric fields measured by the Millstone Hill incoherent scatter radar. The level of auroral activity was given in terms of hemispherical power input due to particle precipitation. The model of high-latitude energy input was incorporated into a zonally averaged thermospheric model. This paper presents the results of a simulation done for the period September 18–14, 1984. Time histories of the composition are given as well as those of dynamical parameters such as temperature and winds. The spatial structures in these parameters are also discussed. The main new result of the simulation is that during auroral disturbances the radiative cooling by nitric oxide (NO) is greatly enhanced by the increase in NO number density as well as by the temperature increase. As a result the temperature increase in response to auroral activity is damped, and the temperature relaxation time is shortened following a quieting of activity. A comparison between the simulated temperatures and the temperatures observed by the Millstone Hill incoherent scatter radar during the 7-day interval shows reasonable agreement in terms of the absolute magnitude of the variations as well as the time constants of those variations.

SE–030

McINTOSH, P.S., The classification of sunspot groups. Solar Physics 125: 251–267 (1990).

The 3-component McIntosh classification of sunspots was introduced in 1966, adopted for interchange and publication in 1969, and has been used increasingly in recent years. The McIntosh classification uses a modified Zurich evolutionary sequence as its first component, class, where two of the Zurich classes are omitted and more quantitative definitions are used. It then adds descriptions of the largest spot (second component) and the degree of spottedness in the group interior (third component) to define 60 distinct types of sunspot groups. Definitions of the McIntosh classification system and their rationale are presented herein. Correlations with solar flares excel those with the earlier Zurich classification, prompting the use of the McIntosh classification system in an expert system (Theo) for predicting x-ray solar flares.

SE–031

Nitta, N., B.R. Dennis, and A.L. Kiplinger, X-ray observations of two short but intense solar flares. The Astrophysical Journal 353: 313–322 (1990).

We present continuum x-ray spectra of impulsive emission in two short but intense solar flares which have relatively weak soft x-ray emissions, combining data obtained with soft x-ray and hard x-ray spectrometers on board two satellites, the Solar Maximum Mission (SMM) and Hinotori. In both flares, photon spectra of the impulsive component are found to flatten toward low energies, suggesting

that a low-energy cutoff of the electron spectrum could be $\geq$ 50 keV and that the total energy contained in the electrons is significantly less than that usually quoted for a cutoff energy of ~20 keV. Different shapes of the x-ray spectrum at energies below 50 keV in other flares can be attributed to the variety in the relative strength of gradual and impulsive emissions. In one of the two flares, observations with the imager on Hinotori suggest that hard x-ray emission is likely to be associated with loop footpoints. However, conjugate footpoints have unequal brightnesses suggesting asymmetry of the loop magnetic field. It is argued that contamination by the gradual soft x-ray emission and/or the asymmetry of loops could explain the detection of single sources in the majority of flares that have been imaged in hard x-rays.

SE–32

Pap, J., H.S. Hudson, G.J. Rottman, R.C. Willson, R.F. Donnelly, and J. London, Modeling solar Lyman alpha irradiance. In Climate Impact of Solar Variability, Proceedings of a conference held at NASA Goddard Space Flight Center, Greenbelt, MD, April 24–27, 1990, NASA Conference Publication 3086, K.H. Schatten and A. Arking (eds.), NASA, Greenbelt, MD, pp. 189–196 (1990).

Solar Lyman alpha irradiance is estimated from various solar indices using linear regression analyses. Models developed with multiple linear regression analysis, including daily values and 81-day running means of solar indices, predict reasonably well both the short- and long-term variations observed in Lyman alpha. It is shown that the full disk equivalent width of the He line at 1083 nm offers the best proxy for Lyman alpha, and that the total irradiance corrected for sunspot effect also has a high correlation with Lyman alpha.

SE–033

Pap, J., and B. Vrsnak, Solar irradiance variations and their relation with solar flares. In Solar and Stellar Flares, IAU Colloquium No. 104, 15–19 August 1988, Stanford University, California, B.M. Haisch and M. Rodono (eds.), pp. 243–246 (1989).

A clear association is demonstrated between the dips in the total solar irradiance and flare occurrence. It is found that both the irradiance dips and flares are related to emerging new activity.

SE–034

Pinter, S., and M. DRYER, Conversion of piston-driven shocks from powerful solar flares to blast wave shocks in the solar wind. Bull. Astron. Inst. Czechosl. 41: 137–148 (1990).

It has been suggested by Smart and Shea (1985) that the time of arrival of solar-flare-generated shock waves at any point in space may be predicted by assuming that they are first driven from the Sun after which they decay into blast shocks. We extend their study by using the duration of the Type IV radio emission as a phenomenological symptom of the piston-driven phase of these shocks. Using a sample of 39 cases of combined Type II/Type IV observations from 1972–1982 solar flares, we find using our model that the average predicted times-of-arrival of these shocks at Earth (and elsewhere) deviate from the actual times by 1 40 hr with a standard deviation of 1.25 hr. On the average, a representative shock from this sample is emitted from a powerful flare with a velocity of 1560 km sec^{-1}; moves at constant inertial velocity to a distance of 0 12 AU after which it begins its deceleration as a classical (Sedov-type) blast shock that is convected by the ambient solar wind as suggested by Smart and Shea; and arrives at Earth 45 8 hr after its initiation at the Sun. Shocks that appear to deviate from this phenomenological scenario by virtue of lack of detection at Earth are assumed to decay into fast-mode MHD waves.

SE–035

Poquerusse, M., and P.S. McINTOSH, Type III radio burst productivity in solar flares. In Solar and Stellar Flares, IAU Colloquium No. 104, 15–19 August 1988, Stanford University, California, B.M. Haisch and M. Rodono (eds.), pp. 177–180.

We study the statistical relationship between optical flares and type III radio bursts, using modern and extensive computer files. Results emerge along two main lines, concerning the physical mechanism of ejection of energetic particles, and the magnetic field geometry, respectively. First, we find that type III probability of occurrence increases strongly with the brightness of a flare and its proximity to a sunspot, and with accompanying prominence activity. This suggests that Bornmann's Class I and III events correspond to distinct physical phenomena, particle acceleration, and magnetic expansion, respectively, both working simultaneously in class II events, which are the most favorable to the ejection of energetic particles out of flaring sites. Second, we find that type III probability is maximum for flares at about 30 degrees east of the central meridian and one degree west of the center of the main group of flares in a given active region. We conclude that field lines on the west side of an active region are the most likely to be open onto the interplanetary medium and that they are on the average tilted 30 degrees westward.

SE-036

Richardson, I.G., C.J. Owen, S.W.H. Cowley, A.B. Galvin, T.R. Sanderson, M. Scholer, J.A. Slavin, and R.D. ZWICKL, ISEE 3 observations during the CDAW 8 intervals: Case studies of the distant geomagnetic tail covering a wide range of geomagnetic activity. Journal of Geophysical Research 94: 15,189–15,220 (1989).

The data obtained by the ISEE 3 spacecraft during the eight Coordinated Data Analysis Workshop 8 (CDAW 8) intervals provide an excellent opportunity to study the structure and dynamics of the distant geomagnetic tail under a wide range of geomagnetic activity ranging from intervals of magnetic quiet punctuated by isolated substorms to extended intervals of strong disturbance. By examining the properties of the plasma sheet, evidence has been found for the persistence of reconnection in the tail during long intervals of magnetic quiet, with the neutral line lying $\sim$ 100 to 200 R_E or more downtail. The suggestion that the distant tail plasma sheet is populated exclusively by tailward moving closed flux tubes under quiet geomagnetic conditions is therefore not supported. However, a "slow plasma sheet" regime is also found during such conditions, in which closed flux tubes move slowly tailward in a thick region adjacent to the magnetopause, presumably due to some form of "viscous" momentum transfer from the magnetosheath. This process does not appear to simultaneously transfer mass into the tail, and there is some indication that the Kelvin-Helmholtz instability is involved. The observations strongly suggest that the closed flux tubes originate from the closed field line plasma sheet region earthward of the neutral line rather than, for example, from the near-Earth low-latitude boundary layer. Plasmoids are observed in the distant tail following disturbance enhancements, the time of their appearance being generally consistent with disconnection from the near-Earth region at the time of the enhancement. Their structure is entirely consistent with the "neutral line" model. However, not all enhancements in geomagnetic activity result in the observation of plasmoids. In particular, the CDAW 8 data suggest that during extended intervals of strong activity, the neutral line may reside in the near-Earth tail (< 60 R_E from Earth) on an essentially continuous basis and that some disturbance enhancements may then relate to an increase in the reconnection rate at a pre-existing neutral line, rather than to new neutral line, and plasmoid, formation. The plasma sheet downtail of the neutral line then thickens and may engulf the spacecraft, but no plasmoid signatures are present.

SE-037

Richmond, A.D., Y. Kamide, S.-I. Akasofu, D. Alcayde, M. Blanc, O. de la Beaujardiere, D.S. EVANS, J.C. Foster, E. Friis-Christensen, J.M. Holt, R.J. Pellinen, C. Senior, and A.N. Zaitzev. Journal of Geophysical Research 95(A2): 1061–1071 (1990).

An analysis of several global measures of high-latitude ionospheric electrodynamic activity is undertaken on the basis of results obtained from the Assimilative Mapping of Ionospheric Electrodynamics (AMIE) procedure applied to incoherent scatter radar and ground magnetometer observations for January 18–19, 1984. Different global measures of electric potentials, currents, resistances, and energy transfer from the magnetosphere show temporal variations that are generally well correlated. We present parameterizations of these quantities in terms of the AE index and the hemispheric power index of precipitating auroral particles. It is shown how error estimates of the mapped electric fields can be used to correct the estimation of Joule heating. Global measures of potential drop, field-aligned current, and Joule heating as obtained by the AMIE procedure are compared with similar measures presented in previous studies. Agreement is found to within the uncertainties inherent in each study. The mean potential drop through which field-aligned currents flow in closing through the ionosphere is approximately 28% of the total polar cap potential drop under all conditions during these 2 days. We note that order-of-magnitude differences can appear when comparing different global measures of total electric current flow and of effective resistances of the global circuit, so that care must be exercised in choosing characteristic values of these parameters for circuit-analogy studies of ionosphere-magnetosphere electrodynamic coupling.

SE-038

Rosenthal, D.A., and J.W. HIRMAN, A Radio Frequency User's Guide to the Space Environment Services Center Geophysical Alert Broadcasts. NOAA Technical Memorandum ERL SEL–80, 19 pp. (1990).

The National Oceanic and Atmospheric Administration's hourly short-wave radio bulletins provide continually updated information on solar-activity-induced effects on the near-Earth space environment. Bulletins are 45 seconds or less in duration and contain a large amount of useful data. This User's Guide explains the standardized format and terminology of the bulletins. Specific terms are highlighted in bold type the first time they occur, and are defined in an appendix.

SE-039

RUFENACH, C.L., R.F. Martin, Jr., and H.H. SAUER, A study of geosynchronous magnetopause crossings. Journal of Geophysical Research 94: 15,125–15,134 (1989).

Sixty-four magnetopause crossings at geosynchronous orbit were detected by the GOES 2, 5, and 6 satellites between 1978 and 1986. The total accumulated crossing duration was 4 hours/year, or about 0.1% of the time. These rare events permit investigation of the interaction of the solar wind with the magnetosphere. This interaction has been examined through comparisons of solar wind and geophysical parameters during crossing episodes, and through superposed epoch event analysis of these periods. The study suggests that both high solar wind dynamic pressures and southward interplanetary B_z are required for the excursion of the magnetopause to geostationary orbit and beyond. Thus dynamic pressure alone is not sufficient to produce a magnetopause crossing; some erosion seems also to be required. An approximate relationship between the strength of the southward B_z and the subsolar distance to the magnetopause

boundary has been obtained: $\Delta R(R_E) = 0.08\ B_z$ (nT) where ΔR is the change in standoff distance attributed to erosion. Further, magnetopause crossings are associated with the more intense, sudden-commencement geomagnetic storms. On average, storm sudden commencements occur 5 hours before a crossing, while an average B_z turns southward 7 hours before the crossing.

SE-040

Sanderson, T.R., M.A. Albrecht, K. Blank, M. Brett, A. Ciarlo, J.L. Green, H.K. Hills, P.M.T. Hughes, T. Kamei, A. Kiplinger, R.E. McGuire, J.H. Waite, and G. Wallum. World-wide interactive access to scientific databases via satellite and terrestrial data network. In Interactive Access to Scientific Databases, ESA Bulletin 61, European Space Agency, Paris, pp. 63-69 (1990).

No abstract.

SE-041

SAUER, H.H., NOAA/TIROS and GOES observations of galactic and solar cosmic rays over a solar cycle. In Climate Impact of Solar Variability, Proceedings of a conference held at NASA Goddard Space Flight Center, Greenbelt, MD, April 24-27, 1990, NASA Conference Publication 3086, K.H. Schatten and A. Arking (eds.), NASA, Greenbelt, MD, pp. 118-124 (1990).

Correlations between solar activity and atmospheric processes have been investigated for more than 30 years, and the reality of the strong correlations found has been well accepted. However, it remains problematic to establish mechanisms capable of coupling the physical manifestations of solar variability to the lower atmosphere. There has been to date a lack of long-term satellite measurements of particles of sufficient energy to penetrate the Earth's atmosphere. The NOAA Space Environment Laboratory has maintained energetic particle detectors on board both the NOAA/TIROS and GOES series of satellites. These instruments monitor the flux of energetic protons to energies greater than about 800 MeV. Measurement of particles above 350 MeV began October 1978, and continue to date. The instruments are briefly described, along with the current program to reduce the data. The goal is to provide a data base that will help to assess the significance of variations of atmospheric and ionospheric properties due to energetic particle precipitation.

SE-042

Siskind, D.E., C.A.Barth, D.S. EVANS, and R.G. Roble, The response of thermospheric nitric oxide to an auroral storm, 2. Auroral latitudes. Journal of Geophysical Research 94: 16,899-16,911 (1989).

An analysis of the response of lower thermospheric nitric oxide (NO) at auroral latitudes to the auroral storm of September 19, 1984, is presented. A comparison of data from the Solar Mesosphere Explorer (SME) taken 1 day after the storm (September 20) with data obtained 1 day before the storm (September 18) revealed a factor of 3 increase in NO. In order to model this response, particle data from the NOAA 6 and 7 satellites are used to assess the time history of the auroral energy input along each SME orbital track. The deduced fluxes and characteristic energies are used as input to a time dependent one-dimensional, photochemical model. In addition, the NCAR thermospheric general circulation model (TGCM) is used to calculate the response of the background neutral atmosphere to auroral forcings such as Joule and particle heating. It was found that particle precipitation accounted for 90% of the increase in the peak NO density, although Joule heating was more important at the higher altitudes (> 140 km). The results of the model calculations predict an NO enhancement; however, the amplitude of the response as well as the absolute magnitude of the calculated NO density greatly exceed the observations. Two possibilities are proposed to explain this discrepancy. The first is that the yield of $N(^2D)$ from electron impact on N_2 may only be 50%, rather than the 60-75% previously assumed. The second is that vertical winds of the order of 1-5 m s^{-1} may be generated in an E region auroral arc.It is sown that such winds could be important in damping out the NO response to increased particle precipitation.

SE-043

Slavin, J.A., D.N. Baker, J.D. Craven, R.C. Elphic, D.H. Fairfield, L.A. Frank, A.B. Galvin, W.J. Hughes, R.H. Manka, D.G. Mitchell, I.G. Richardson, T.R. Sanderson, D.J. Sibeck, E.J. Smith, and R.D. ZWICKL, CDAW 8 observations of plasmoid signatures in the geomagnetic tail: An assessment. Journal of Geophysical Research 94: 15,153-15,175 (1989).

A primary objective of the coordinated Data Analysis Workshop 8 (CDAW 8) was the critical assessment of the plasmoid hypothesis. In this study, various types of magnetic phenomena, including closed loops and flux ropes, were considered as candidates for producing the north-then-south magnetic field perturbations characteristic of the "plasmoids" observed in the magnetotail by ISEE 3 during the CDAW 8 A and G events. For these two events the principal axis analyses of the magnetic field data and supporting energetic particle and plasma measurements are found to be consistent with the closed-loop model of plasmoids for which the plane of rotation for B lies near the GSE X-Z plane and only small field components lie in the minimum variance direction oriented largely along the Y direction. While small pitch angle spiraling of the field lines within these structures such as suggested by Hughes and Sibeck (1987) and Birn et al. (1989) cannot be definitively measured using single-spacecraft magnetometer observations, the ISEE 3 measurements are not consistent with moderate strength or Venus-type, strong core field flux ropes. The event A and G plasmoids were preceded by smoothly draped lobe field lines and followed by strong southward fields in the postplasmoid plasma sheet as predicted by the reconnection model of substorms. This latter feature of the observations is consistent with plasmoids moving down the tail, at least in part, due to the Maxwell stress exerted by lobe field lines which were disconnected at the near-tail neutral line and have draped about the

earthward side of the plasmoid. Calculations, based upon typical plasmoid and tail parameters, are presented which indicate that the J x B force associated with these disconnected lobe field lines may be sufficient to accelerate plasmoids up to the speeds observed by ISEE 3. A new characteristic of the plasmoid signature identified in this study is the presence of enhanced internal magnetic fields which can exceed the magnitude of the adjacent lobe fields by as much as 10-20%. While the internal structure of plasmoids remains poorly understood, an extension of the traveling compression region model (Slavin et al.,1984) is proposed to explain these high field regions. Finally, the relationship between the nature of individual substorms and the characteristics of the plasmoids observed in the tail by ISEE 3 is considered. The event A observations suggest that during isolated substorms the magnetotail may undergo an interval of intense reconnection which results in the creation of a single large plasmoid. Extended substorm intervals, exemplified by event G, may produce numerous smaller plasmoids as X lines form in the cislunar tail and retreat tailward while the magnetosphere continues to draw energy from the solar wind. Overall, the energy expended in accelerating the plasmoid down the tail appears comparable to that dissipated in the inner magnetosphere and ionosphere. Additional studies of plasmoid structure and dynamics as a function of substorm activity and distance down the tail should be conducted to determine the general validity of the conclusions reached on the basis of the CDAW 8 events.

SE-044

Steinegger, M., P.N. Brandt, J. Pap, and W. Schmidt., Sunspot photometry and the total solar irradiance deficit measured in 1980 by ACRIM. Astrophysics and Space Sciences 170: 127-133 (1990).

Until now a simple Photometric Sunspot Index (PSI) model was used (e.g. Willson et al., 1981) to describe the contribution of sunspots to the solar irradiance deficit measured by ACRIM. In this work we replace this model by a photometry of sunspot pictures for the period of 19 Aug. to 4 Sept. 1980 taking into account the individual features, like lightbridges or umbral dots, of each spot. The main results of this preliminary analysis are: 1) the A_u/A_p ratios and also the α values vary in a wide range and are by no means constant as in the PSI model; 2) the general trend of the irradiance deficit derived from our analysis agrees well with the ACRIM measurements; (3) on some days there are differences of more than 50% between the deficits derived from our measurements and from the PSI model.

SE-045

Szuszczewicz, E.P., P. Wilkinson, M.A. Abdu, E. Roelof, R. Hanbaba, M. Sanda, T. Kikuchi, R. Burnside, J. JOSELYN, M. Lester, R. Leitinger, G.O. Walker, B.M. Reddy, and J. Sobral, Solar-terrestrial conditions during SUNDIAL-86 and empirical modelling of the global-scale ionospheric response. Annales Geophysicae 8(6): 387-398 (1990).

Covering the period from 22 September through 4 October 1986, the SUNDIAL-86 Solar-Minimum Equinoctial Campaign studied the behavior of the global-scale ionosphere. The period covered the most quiet (Q1) and second most disturbed (D2) days of the entire month of September, with the disturbed conditions triggered by a high-speed solar wind stream. Ionospheric responses were monitored by the SUNDIAL network of nearly 70 stations distributed approximately in three longitudinal domains; and global maps of f_oF_2 results were compared with the "predictions" of the International Reference Ionosphere modified to include an empirical specification of auroral oval boundaries and associated high-latitude morphological domains. Comparisons that included regions in the polar cap, diffuse auroral oval, mid-latitude trough, equatorial anomaly and the sunrise/sunset terminator showed good agreement between the hourly 8-day-averaged ionospheric observations and the model. The inclusion of an auroral oval and the good agreement between model contours of f_oF_2 and SUNDIAL observations adds to the quality and applicability of the IRI and builds a foundation for the development of an adaptive time-dependent empirical model to describe global-scale ionospheric responses to storm dynamics.

SE-046

Tappin, S.J., Z.K. SMITH, and M. DRYER, Scintillation, density, and turbulence in the interplanetary medium. Planetary and Space Science 38(8): 955-960 (1990).

An attempt is made to reconcile the different power laws obtained when relating, on the one hand, interplanetary scintillation (IPS) to solar-wind density and, on the other, density turbulence to density. A numerical experiment was performed using a 2-D magnetohydrodynamical (MHD) model to simulate the solar wind in the ecliptic plane and then generating IPS g values by line-of-sight integration through the model solar wind. This simulation showed that any breakdown of the assumptions implicit in comparing a line-of-sight integral with a time average made near Earth was insufficient to account for the difference.

SE-047

Tobiska, W.K., Modeled solar EUV flux during the Equinox Transition Study: September 17-24, 1984. NOAA Contract NA85RAH06066. Journal of Geophysical Research 94(A12): 17,017-17,020 (1989).

A new empirical model of solar extreme ultraviolet (EUV) irradiance variability has been developed based on satellite and rocket EUV observations for all levels of solar activity. Its results for the Equinox Transition Study (ETS) period of September 17-24, 1984, have been calculated, and the tabulated results of photon and energy fluxes for each day of this period are presented. The model average total EUV full-disk energy flux for the spectral range between 1.9 and 105.0 nm for the ETS period is 2.9 ergs cm^{-2} s^{-1}, with a general secular increase in the total flux level between September 17 and September 24. This modeled

rise corresponds to the increased EUV irradiance variability due to active region evolution and passage across the disk. The modeled EUV values in September 1984 near solar cycle 21 minimum conditions are higher than rocket- and satellite-measured EUV values near solar minimum conditions of cycle 20. However, the risks are consistent with recent trends in the literature to revise the solar cycle 20 minimum flux values upward.

SE-048

Tobiska, W.K., SERF2: A Solar Extreme Ultraviolet Flux Model. Contribution No. 9, Earth and Planetary Atmospheres Group, Space Sciences Lab., University of California, Berkeley, NOAA Contract N85RAH05066, 237 pp. (1990).

A model of the solar extreme ultraviolet (EUV) irradiance variability has been developed for aeronomical use and has been named SERF2 by the Solar Electromagnetic Radiation Flux study. The model is valid between 1981 and 1989 and is based on the Atmosphere Explorer-E (AE1-E) satellite EUV dataset which is correlated with independent solar emissions measured during and after the AE-E mission. Additionally, spectral modifications are made to the model based on eighteen separate rocket flights for all levels of solar activity. Two daily measured solar emissions, the H Lyman-α line at 121.6 nm observed by the Solar Mesosphere Explorer (SME) satellite and the Ottawa 10.7-cm radio flux observed at the ground, are used in the model as indices for full-disk solar EUV chromospheric irradiance variations and transition region-coronal irradiance variations, respectively. The model wavelength equation coefficients are presented in tabular form for 39 wavelength groups or discrete lines from 1.9-105.0 nm along with spectral weighting function coefficients which modify the irradiance magnitudes based upon model wavelength fits to rocket-observed spectra. The model satisfies the general constraint of duplicating rocket-observed EUV irradiance for a wide variety of solar activity conditions. The model development is discussed, an example calculation is given, the comparisons with constraining rocket datasets are shown, and the differences between this EUV irradiance model and the previous SERF1 model are discussed. Finally, comparisons are made between SERF2 and the AEROS A, OSO 3, OSO 4, and OSO 6 EUV datasets for similar solar activity and conditions.

SE-049

Tobiska, W.K., and C.A. Barth, A solar EUV flux model. Journal of Geophysical Research 95(A6): 8243-8251 (1990).

A model of the solar extreme ultraviolet (EUV) irradiance variability has been developed for aeronomical use and has been named SERF2 by the Solar Electromagnetic Radiation Flux Study. The model is valid between 1981 and 1989 and is based on the Atmosphere Explorer E (AE-E) satellite EUV data set which is correlated with independent solar emissions measured during and after the AE-E mission. Additionally, spectral modifications are made to the model based on 18 separate rocket flights for all levels of solar activity. Two daily measured solar emissions, the H Lyman α line at 121.6 nm observed by the Solar Mesosphere Explorer satellite and the Ottawa 10.7-cm radio flux observed at the ground, are used in the model as indices for full-disk solar EUV chromospheric irradiance variations and transition region-coronal irradiance variations, respectively. The model wavelength equation coefficients are presented in tabular form for 39 wavelength groups or discrete lines from 1.9 to 105.0 nm along with spectral weighting function coefficients which modify the irradiance magnitudes based upon model wavelength fits to rocket-observed spectra. The model satisfies the general constraint of duplicating rocket-observed EUV irradiance for a wide variety of solar activity conditions. The model development is discussed, an example calculation is given, and the comparisons with constraining rocket data sets are shown.

SE-050

WAGNER, W.J., Taking the first steps in real-time EUV monitoring for drag: The series of USAF-NOAA Solar X-Ray Imagers (SXIs) on GOES. In Atmospheric Density and Aerodynamic Drag Models for Air Force Operations, Proceedings of Workshop held at AFGL, 20-22 October 1987 (F.A. Marcos, ed.), GL-TR-90-0033(II), ERP No. 1053, pp. 8-13 - 8-15 (1990).

Real-time 255-300 Å whole-Sun flux data at high cadence rates will be available for input to neutral density models after launch of the USAF-NOAA Solar X-Ray Imager. It is expected that SXI will contribute significantly to reducing the losses due to drag and orbital decay of both NASA and DOD space systems.

SE-051

Wilson, P.R., R.F. DONNELLY, and G.P. Wilkinson, The Solar Cycle Workshop (a review). Solar Physics 125: 159-172 (1990).

The contributions to the third meeting of the Solar cycle Workshop are briefly summarized. The topics discussed at the meeting included (i) predictions and precursors, (ii) large and small-scale magnetic fields, (iii) photospheric velocity fields, (iv) coronal phenomena, (v) the Sun as a star, (vi) limb temperature measurements and helioseismic data, (vii) theoretical modeling of the cycle, (viii) cyclic activity in stars, and (ix) the interpretation of the Elatina Sandstone Layers.

SE-052

Wilson, P.R., P.S. McINTOSH, and H.B. Snodgrass, The reversal of the solar polar magnetic fields. I. The surface transport of magnetic flux. Solar Physics 127: 1-9 (1990).

Some theoretical difficulties confronting the current model of the polar magnetic reversal by cancellation with the flux remnants of decaying active regions are discussed. It is shown that the flux transport equation does not adequately describe the essential physical

consequences of the transport of large-scale fields, linked to deep subsurface toroids, over distances comparable with the solar radius. The possibility that subsurface reconnections may release these fields to form U-loops is discussed, but it is shown that, in this event, the loops will quickly rise to the surface. Mechanisms whereby the flux may escape through the surface are considered.

SE-053

Wu, S.T., An Analysis of Potential Techniques for the Improvement of Numerical Simulation of Coronal/Interplanetary/ Ionospheric Coupled Flows. Final Report, NOAA Contract R50RANR700099. Engineering International, Inc., Huntsville, Alabama, 174 pp. (1990).

No abstract.

SE-054

Yeh, T., A dynamical model of prominence loops. Solar Physics 124: 251-269 (1989).

A dynamical model of prominence loops is constructed on the basis of the theory of hydromagnetic buoyancy force. A prominence loop is regarded as a flux rope immersed in the solar atmosphere above a bipolar region of the photospheric magnetic field. The motion of a loop is partitioned into a translational motion, which accounts for the displacement of the centroidal axis of the loop, and an expansional motion, which accounts for the displacement of the periphery of the loop relative to the axis. The translational motion is driven by the hydromagnetic buoyancy force exerted by the surrounding medium of the solar atmosphere and the gravitational force exerted by the Sun. The expansional motion is driven by the pressure gradient that sustains the pressure difference between internal and external gas pressures and the self-induced Lorentz force that results from interactions among internal currents. The main constituent of the hydromagnetic buoyancy force on a prominence loop is the diamagnetic force exerted on the internal currents by the external currents that sustain the pre-existing magnetic field. By spatial transformation between magnetic and mechanical stresses, the diamagnetic force is manifested through a mechanical force acting at various mass elements of the prominence. For a prominence loop in equilibrium, the gravitational force is balanced by the hydromagnetic buoyancy force and the Lorentz force of helical magnetic field is balanced by a gradient force of gas pressure.

Addendum

SE-055

BORNMANN, P.L., Is the plasma truly turbulent during the impulsive phase of solar flares? In Solar System Plasma Physics, Geophysical Monograph 54, J.W. White, Jr., J.L. Burch, and R.L. Moore (eds.), American Geophysical Union, pp. 209-211 (1989).

Solar Maximum Mission observations of line shifts and line broadenings in soft x-ray lines during the impulsive phase of solar flares have generally been accepted as indications of plasma turbulence. In support of this, the rate of decay of the line shifts and line broadenings is consistent with the rate of decay of fluid turbulence. However, the turbulent line broadening interpretation has recently been disputed. They argue that at high time resolution the spectrum consists of discrete, random, wavelength-shifted features and that the apparent turbulent line profiles are the result of integrating these discrete features over long time periods. I consider whether these discrete features are truly random. Preliminary results of this new analysis of these features are presented. I attempt to determine if these discrete features are actually appearing randomly at discrete wavelengths or are moving continuously to new wavelengths. I also consider whether the appearance of these discrete features could be the result of instrumental effects.

SE-056

Cuperman, S., L. Ofman, and M. DRYER, Reply. Journal of Geophysical Research 94(A8): 10,153 (1989).

No abstract.

SE-057

GARCIA, H.A., The evaluation of energy storage mechanisms in the gradual phase of solar flares. In Solar System Plasma Physics, Geophysical Monograph 54, J.W. White, Jr., J.L. Burch, and R.L. Moore (eds.), American Geophysical Union, pp. 213-217 (1989).

Current wisdom provides that the basically thermal character of the gradual phase of a solar flare is a tertiary effect, resulting from the gradual release of energy from the ablated products of chromospheric evaporation. Our studies which quantitatively incorporate the measured bulk flows and the turbulent flows in a comprehensive flare energetics model tend to confirm this theory. The model is a boundary value problem which solves the one-dimensional energy equation semi-empirically for plasma density, utilizing continuous time-referenced electron temperatures, emission measures, and velocity measurements. Observed variations in enthalpy of the flaring plasma are equated to the energy sources and modeled loss mechanisms.

SE-058

WAGNER, W.J., CME and solar wind studies using GOES solar x-ray imagers and SOHO remote sensing. In Solar System Plasma Physics, Geophysical Monograph 54, J.W. Waite, Jr., J.L. Burch, and R.L. Moore (eds.), American Geophysical Union, pp. 279-285 (1989).

All inputs to the heliosphere and to planetary magnetospheres and ionospheres are generated in the plasma which constitutes the outer layers of the solar atmosphere. Although the NASA Solar Maximum Mission satellite is expected to re-enter the atmosphere this year, the outlook for observational studies of the solar corona in the mid-1990s looks optimistic. A variety of new instruments will be available for investigations of solar plasma physics processes. Of preeminent importance is the NASA-ESA SOHO satellite, to be stationed at the L_1 libration point from 1995. I describe SOHO EUV spectrographic and coronagraphic capabilities for use in identifying these inputs to the magnetosphere as they leave the transition region and high corona. To these data will be added views of launches of coronal mass ejections and the unambiguous locations of soft x-ray coronal holes and magnetic structure in the lower corona. The latter will be recorded by the solar x-ray imagers on the NOAA GOES satellites beginning in 1992 or 1993. I also review the ground-based observational capabilities which are expected to be upgraded in time for the solar cycle maximum campaigns beginning in 1991. The tailoring of the above sensor array to the outstanding problems in mass ejection and coronal research is noted.

WAVE PROPAGATION LABORATORY

WP-001

Albrecht, B.A., C.W. FAIRALL, D.W. Thomson, A.B. White, J.B. SNIDER, and W.W. Schubert. Surface-based remote sensing of theobserved and adiabatic liquid water content of stratocumulus clouds. Geophysical Research Letters 17:89-92 (1990).

A laser ceilometer, an acoustic sounder, and a microwave radiometer were used to estimate cloud thickness and the adiabatic and integrated liquid water content of shallow stratocumulus clouds continuously for three days using two-minute averages. Although the observed liquid water path was close to the theoretical adiabatic value for most of the three days, there was one four-hour period when the liquid water content dropped to about 50% of the adiabatic value. Hourly-averaged values for a 19-day period of intensive observations show that the cloud water content was generally close to the adiabatic value. Occasionally there were clouds greater than 300 m in depth in which the water content was clearly less than adiabatic.

WP-002

Alishouse, J.C., J.B. SNIDER, E.R. WESTWATER, C. Swift, C. Ruff, S. Snyder, J. Vongsathorn, and R.R. Ferraro. Determination of cloud liquid water content using the SSM/I. IEEE Transactions on Geoscience and Remote Sensing 28:817-822 (1990).

As part of a calibration/validation effort for the special sensor Microwave/Imager (SSM/I), coincident observation of SSM/I brightness temperatures and surface-based observations of cloud liquid water were obtained. These observations were used to validate initial algorithms and to derive an improved algorithm. The initial algorithms were divided into latitudinal-, seasonal-, and surface-type zones. It was found that these initial algorithms, which were of the D-matrix type, did not yield sufficiently accurate results. The surface-based measurements were used to derive new matrix coefficients. Various combinations of channels were investigated; however, the 85V channel was excluded because of excessive noise. It was found that there is no significant correlation between the SSM/I brightness temperatures and the surface-based cloud liquid water determination when the background surface is land or snow. A high correlation is found between brightness temperatures and ground-based measurements over the ocean.

WP-003

ASH, E., B. Eaton, and K. Gustafson. Counting the number of solutions in combustion and reactive flow problems. Journal of AppliedMathematics and Physics (ZAMP) 41:558-578 (1990).

Computational methods and comparison theory enable, when combined, an enhanced capability for counting the number of solutions in combustion equations. Very good lower bounds for the last turning point reveal a stable high temperature "explosion branch" for very small positive exothermicity.

WP-004

Bahar, E. Scattering of acoustic waves in irregular layered media: full wave solutions. Journal of Wave Motion 12:53-65 (1990).

A full wave approach is used to derive the complete expressions for the acoustic waves excited by line sources in irregular layered media. It is assumed that the height of the interface between the stratified media, the adiabatic bulk modulus, the equilibrium density, and the absorption of the media vary along the path of propagation. The acoustic pressure and velocity are represented completely in terms of their generalized Fourier transforms, and exact boundary conditions are imposed at the irregular interface. The equations of continuity and force are converted into rigorous first-order coupled differential equations for the forward- and backward-scattered wave amplitudes. The equations for the wave amplitudes are solved iteratively to account for the singly scattered far fields.

WP-005

BANTA, R. The role of mountain flows in making clouds. In Atmospheric Processes Over Complex Terrain (Chapter 9). Meteorological Monograph, American Meteorological Society, Boston, MA, 229-283 (1990).

The major focus of this chapter is on unstable mountain clouds (especially mountain thunderstorms) that result from a mixture of large- and small-scale effects. Whereas larger-scale processes control whether or not thunderstorms will be able to form, the role of the mountain (i.e., smaller-scale) circulations is in the initiation or triggering of thunderstorms. Thus mountains have an important role in the temporal and spatial distribution of storms. Three major kinds of lifting that lead to thunderstorm initiation are direct orographic forced lifting to the LFC, convergence of thermally forced circulations, and aerodynamics or obstacle effects.

WP-006

BANTA, R., L. Olivier, and J.M. Intrieri. Doppler lidar observations of the 9 January 1989 severe downslope windstorm in Boulder, CO.Preprints, 5th Conference on Mountain Meteorology, Boulder, CO, 25-29 June 1990. American Meteorological Society, Boston, MA, 68-69 (1990).

No abstract.

WP-007

BEDARD, A.J., JR. Using sensors for physical scale modeling of atmospheric fields. Proceedings, Sensors Expo West, Long Beach, CA, 13-14 March 1990, Sensors (The Journal of Machine Perception), Peterborough, NH, 303B1-303B10 (1990).

No abstract.

WP-008

Bond, N.A., and SHAPIRO, M.A. Research aircraft measurements of a cold front/rope cloud over the ocean. Extended Abstracts, 4thConference on Mesoscale Processes, Boulder, CO, 25-29 June 1990. American Meteorological Society, Boston, MA, 36 (1990).

No abstract.

WP-009

Cahalan, R.F., and J.B. SNIDER. Marine stratocumulus structure. Remote Sensing of the Environment 28:95-107 (1989).

Thirty-three Landsat TM scenes of California stratocumulus cloud fields were acquired as part of the FIRE Marine Stratocumulus Intensive Field Observations in July 1987. They exhibit a wide variety of stratocumulus structures. Analysis has so far focused upon the 7 July scene, in which aircraft from NASA, NCAR, and the British Meteorological Office repeatedly gathered data across a stratocumulus-fair weather cumulus transition. The aircraft soundings validate the cloud base temperature threshold determined by spatial coherence analysis of the TM thermal band. Brightness variations in the stratocumulus region exhibit a -5/3 power-law decrease of the wavenumber spectra for scales larger than the cloud thickness, about 200 m, changing to a -3 power at smaller scales. Observations by an upward-looking three-channel microwave radiometer on San Nicolas Island also show the -5/3 power-law in total integrated liquid water, suggesting that the larger-scale TM brightness variations are primarily due to variations in the liquid water. The Kolmogorov 5/3 power suggests that for some purposes liquid water in turbulent stratocumulus clouds may be treated as a passive scalar, simply reflecting variations in vertical velocity. This may be tested using the velocities measured by the aircraft.

WP-010

Canavero, F.G., F. Einaudi, E.R. WESTWATER, M.J. FALLS, J. SCHROEDER, and A.J. BEDARD, JR. Interpretation of ground-based radiometric observations in terms of a gravity wave model. Journal of Geophysical Research 95:7637-7652 (1990).

An analysis is presented of 2-hour and 4-hour segments of data taken at Denver, CO, on February 3, 1984, by a ground-based radiometer designed and operated by the Wave Propagation Laboratory of the National Oceanic and Atmospheric Administration (NOAA). The zenith-viewing instrument has two moisture-sensing and four temperature-sensing channels. It is demonstrated that a peak at a period of 10 min. present in spectra of the measured brightness temperature and of the derived geopotential heights thicknesses, and vertically integrated water vapor content, is due to an internal gravity wave generated by wind shear in the jet aloft. This analysis shows that the radiometer has the sensitivity to detect such disturbances and that the mathematical inversion technique used to retrieve the geopotential field and other integrated quantities retains the derived information as well. Finally, a linear expression is derived which relates the brightness temperature to the atmospheric temperature, density, humidity, and cloud liquid perturbation fields.

WP-011

CAPLAN, S.J., A.J. BEDARD, JR. and M.T. Decker. The 700-500 mb lapse rate as an index of microburst probability: an application for thermodynamic profilers. Journal of Applied Meteorology 29:680-687 (1990).

This study validates the predicted association between frequency of dry microburst occurrence and large temperature lapse rate. In applying lapse rate trend data and high time resolution data from remote sensors, we first compared lapse rates from the Denver rawinsonde with the thermodynamic profiler and obtained linear correlation coefficients ranging from .63 to .94. Continuous 20-minute radiometer samples of lapse rate were available throughout the experiment period. The data indicate a critical value of 700-500 mb lapse rate $\geq 8°C\ km^{-1}$ for dry microburst occurrence. Also, we found dry microburst occurrence in the Denver area better correlated with late afternoon lapse rates than with early morning lapse rates: 67% of dry microbursts occurred with 1200 UTC lapse rates $\geq 8°C\ km^{-1}$, while 89% of dry microbursts occurred with 2200 UTC lapse rates $\geq 8°C\ km^{-1}$. We recommend that remote sensor temperature retrievals such as with Radio Acoustic Sounding Systems (RASS) extend to at least 3 km AGL to aid dry microburst nowcasting and forecast verification.

WP-012

CHERTOCK, B. Global monitoring of net solar irradiance at the ocean surface and validation of general circulation model simulations. Proceedings, 14th Climate Diagnostics Workshop, La Jolla, CA, 16-20 October 1989. National Meteorological Center, Washington, DC, 172-177 (1989).

No abstract.

WP-013

CHURNSIDE, J.H. Joint probability-density function of irradiance scintillations in the turbulent atmosphere. Journal of the Optical Society of America-A, 6:1931-1940 (1989).

The log-normally modulated Rician model for the probability-density function of optical irradiance fluctuations caused by refractive turbulence can be obtained by applying central-limit theorem arguments to various aspects of the scattered fields. Each of the resulting Gaussian random variables is assumed to be also jointly Gaussian when it is sampled simultaneously at two points in space, thus extending the model to predict the joint probability-density function of the irradiance fluctuations at two points in space. Good agreement with experimental results is provided by this model.

WP-014

CHURNSIDE, J.H. A spectrum of refractive turbulence in the atmosphere. Optics Letters 37:13-16 (1990).

An analytic approximation to the optical refractive-index spectrum of atmosphere turbulence is presented.

WP-015

CHURNSIDE, J.H., and R.G. Frehlich. Experimental evaluation of log-normally modulated Rician and IK models of optical scintillation in the atmosphere. Journal of the Optical Society of America-A 6:1760-1766 (1989).

Approximating the probability-density function of optical irradiance fluctuations in the turbulent atmosphere under all propagation conditions requires a model with at least two parameters. Two phenomenological two-parameter models that have been proposed, the *IK* and the log-normally modulated Rician probability-density functions, are compared with measured probability-density functions of the irradiance of laser light in a turbulent atmosphere under a variety of propagation conditions. The parameters for each model are obtained from measured second and third moments. It is concluded that the log-normally modulated Rician model is the better approximation to the data. However, the effects of the intermittency of turbulence must be included in the model for short propagation paths.

WP-016

CHURNSIDE, J.H., S.G. Hanson, and S.F. CLIFFORD. Optical remote sensing of wind and turbulence using double spatial filtering of scintillations. Topical Meeting on Optical Remote Sensing of the Atmosphere, Incline Village, NV, 12-15 February 1990. Optical Society of America, Washington, DC, 470/WD2-1-4/473 (1990).

No abstract.

WP-017

CHURNSIDE, J.H., R.J. HILL, G. Conforti, and A. Consortini. Aperture size and bandwidth requirements for measuring strong scintillation in the atmosphere. Applied Optics 28:4126-4132 (1989).

Irradiance statistics were simultaneously measured with five apertures of four different sizes and also with five different bandwidths under conditions of storng path-integrated turbulence to determine aperture size and bandwidth requirements. The probability density function and the second and third moments are considered. Good measurements of these statistics can be made with detector apertures near the wave coherence length and with bandwidths near the ratio of the transverse wind velocity to the wave coherence length under these conditions.

WP-018

Ciotti, P., G. Schiavon, J.B. SNIDER, D. Solimini, P. Tognolatti, and E.R. WESTWATER. Atmospheric observations by ground-based microwave radiometers in three different climatic environments. Proceedings, URSI Commission F Symposium, La Londe-les-Maures, France, 11-15 September 1989, International Union of Radio Science, Issy-les-Moulineaux, France, 1.4.1-1.4.4 (1990).

Microwave radiometers that measure water vapor are becoming increasingly important in a variety of geophysical investigations. In this paper, results are presented of experiments with water vapor radiometers operating in three climatically different locations: San Nicolas

Island, California, USA; Denver, Colorado, USA; and Rome, Italy. In the United States experiments, a three-channel radiometer, operating at 20.6, 31.65, and 90.0 GHz, was used; in Rome, a dual-channel radiometer was operated at 20.6 and 36.0 GHz. Data and theory are presented to illustrate both the differences and the similarities between the various locations.

WP-019

CLIFFORD, S.F., D.F. Farmer, R.J. LATAITIS, and G.B. Crawford. Ocean remote sensing by acoustic scintillation techniques. Proceedings, 5th International Symposium on Acoustic Remote Sensing of the Atmosphere and Oceans, New Delhi, India, 6-9 February 1990. Tata-McGraw Hill, New Delhi, 189-197 (1990).

No abstract.

WP-020

Crawford, G.B., R.J. LATAITIS, and S.F. CLIFFORD. Remote sensing of ocean flows by spatial filtering of acoustic scintillations: Theory. Journal of the Acoustical Society of America, 88:442-454 (1990).

Space-time acoustic scintillation analysis has proved to be a valuable technique for probing ocean flows over short (less than or approximate to 2 km) acoustic paths. Measurements of the amplitude and phase perturbations in a distant receiving plane are used to infer the intervening fine-scale variability and transverse current. Observations made using one transmitter and two receivers yield path-integrated measurements that are almost uniformly weighted along the propagation path. Higher resolution measurements can be obtained using multiple sources and receivers. By combining the signals from each transmitter-receiver pair in different ways, a number of different path positions can be probed and profiles of the fine-scale variability and transverse current along the propagation path retrieved. A theory describing the performance characteristics of such a system is presented. The case of linear transmitting and receiving arrays of equally spaced elements is considered in detail. The theory predicts a potential path resolution of up to $L/[(N'_t + N'_r)/2]$, where $N'_t >> 1$ and $N'_r >> 1$ are the number of transmitters and receivers, respectively, and L is the propagation path length. The specific case of four-element transmitting and receiving arrays is also considered, and some simulations of profile retrievals are presented. A future paper [D.M. Farmer and G.B. Crawford, *(Journal of the Acoustical Society of America)* (in preparation)] will present results of an experiment to test such a system.

WP-021

DONALL, E.G., M.A. SHAPIRO, and P.J. NEIMAN. Mesoscale processes in a rapidly intensifying extratropical marine cyclone. Preprints, 4th Conference on Mesoscale Processes, Boulder, CO, 25-29 June 1990. American Meteorological Society, Boston, MA,94-95 (1990).

No abstract.

WP-022

Douglas, M.W., and M.A. SHAPIRO. A comparison of the structure of two polar lows observed by aircraft. In Polar and Arctic Lows, Twitchell, Rasmussen, and Davidson (eds.). A. Deepak Publishing, Hampton, VA, 291-312 (1989).

The analysis of observations collected from research aircraft flights into two polar lows are presented and compared in order to identify those features common to both. A polar low development northeast of Iceland on 27 February 1984 is compared with a polar low observed on 4 and 5 March 1987 over the northern Gulf of Alaska. Close similarities in the low-level wind fields and thermal structures are reflected in similar satellite cloud signatures. Some previous observational and theoretical studies have attempted to relate polar lows to tropical cyclones; here the structure of the polar lows is briefly compared with a tropical monsoon depression, which shows similarities in both satellite imagery and in aspects of the temperature field, such as the presence of a warm "eye."

WP-023

Douglas, M.W., M.A. SHAPIRO, L.S. FEDOR, and L. Saukkonen. Research aircraft observations of a polar low at the east Greenland ice edge. Proceedings, 4th Conference on Mesoscale Processes, Boulder, CO, 25-29 June 1990. American Meteorological Society, Boston, MA, 22-23 (1990).

No abstract.

WP-024

EBERHARD, W.L., R. CUPP, and K.R. Healy. Doppler lidar measurement of profiles of turbulence and momentum flux. Journal of Atmospheric and Oceanic Technology 6(5):809-819 (1990).

A short-pulse CO_2 Doppler lidar with 150-m range resolution measured vertical profiles of turbulence and momentum flux. Example measurements are reported of a daytime mixed layer with strong mechanical mixing caused by a wind speed of 15 m s^{-1}, which exceeded the speed above the capping inversion. The lidar adapted an azimuth scanning technique previously demonstrated by radar. Scans alternating between two elevation angles allow determination of $\langle u^2 \rangle$, $\langle v^2 \rangle$, and $\langle w^2 \rangle$. Expressions were derived to estimate the uncertainty in the turbulence parameters. A new processing method, partial Fourier decomposition, has less uncertainty than the filtering used earlier. Substantial improvements could be had with higher pulse rate, shorter pulses and wavelengths (to improve spatial resolution and minimum range by up to an order of magnitude), and operation from an aircraft.

WP-025

EBERHARD, W.L., R.E. CUPP, R.M. HARDESTY, J.M. Intrieri, and R.J. Willis. Design and preliminary results from the cloud lidar and radar exploratory test (CLARET). Proceedings, Topical Meeting on Optical Remote Sensing of the Atmosphere, Incline Village, NV, 12-15 February 1990, Optical Society of America, Washington, DC, 212-214 (1990).

No abstract.

WP-026

EBERHARD, W.L., R.M. HARDESTY, M.J. POST, B.J. Rye, and K.R. Healy. Progress in turbulence measurements by Doppler lidar. Preprints, 9th Symposium on Turbulence and Diffusion, Roskilde, Denmark, 30 April-3 May 1990. American Meteorological Society, Boston, MA, 78-81 (1990).

No abstract.

WP-027

EBERHARD, W.L., and G.T. McNice. Lidar observations of stratospheric aerosols in 1988 at Boulder, Colorado. NOAA TM ERL WPL-174, 18 pp. (1989).

Profiles of aerosol scattering ratio measured by ruby lidar at Boulder, Colorado, during 1988 are presented. The 21 profiles were obtained during the fourth year of a continuing program. The aerosol scattering ratio in 1988 was substantially less than in any of the three previous years, continuing a trend toward a "cleaner" stratosphere. The peak in the annual-average profile was only 1.26 and was located at 20 km MSL.

WP-028

EBERHARD, W.L., T. UTTAL, J.M. Intrieri, and R.J. Willis. Cloud parameters from IR lidar and other instruments: CLARET design and preliminary results. Preprints, 7th Conference on Atmospheric Radiation, San Francisco, CA, 23-27 July 1990. American Meteorological Society, Boston, MA, 343-348 (1990).

No abstract.

WP-029

Edson, J.B., C.W. FAIRALL, P.G. Mestayer, and S.E. Larsen. Inertial-dissipation flux estimations: The hexmax results. Preprints, 9th Symposium on Turbulence and Diffusion, Roskilde, Denmark, 30 April-5 May 1990. American Meteorological Society, Boston, MA, 66-69 (1990).

No abstract.

WP-030

FAIRALL, C.W. A gravity wave model of turbulence and variability in the stratified free troposphere. Preprints, 9th Symposium on Turbulence and Diffusion, Roskilde, Denmark, 30 April-3 May 1989. American Meteorological Society, Boston, MA, 384-388 (1990).

No abstract.

WP-031

FAIRALL, C.W. A model of gravity-wave-induced variability and turbulence in the stratified free atmosphere. NOAA TM ERL WPL-179, 65 pp. (1990).

The atmosphere exhibits variability on many spatial and temporal scales. Much of the variability of the free atmosphere can be characterized using an internal gravity wave spectral model such as the one originally developed by Garrett and Munk for the ocean. In this paper we examine the consequences of using a vertical wavenumber spectral model (Sidi et al., 1988) to describe variations of vertical profiles of atmospheric variables (horizontal and vertical wind, temperature, and other scalars) about a mean profile. At high wavenumbers the model exhibits a wavenumber to the -3 dependence, which is characteristic of a continuum of internal gravity waves whose amplitudes are controlled by a breaking process (sometimes referred to as a "saturated" gravity wave spectrum). By employing a random phase between wavenumber amplitude components, a reverse Fourier transform of the spectrum yields simulated profiles of velocity and thermal variability as well as shear and the Brunt-Väisälä frequency exhibit Gaussian distributions; the square of the magnitude of the shear exhibits a Rice-Nakagami distribution. If regions with Richardson number less than a critical value of 0.25 are assumed to be turbulent, then we can examine a number of aspects of the occurrence of clear-air turbulent breakdown in the stratified free atmosphere including the probability distributions for R_i and the vertical extent of turbulent layers. For a typical tropospheric condition, the average turbulent layer thickness turns out to be about 35 m and about 20% of the troposphere appears to be actively turbulent. The majority of the turbulent layers appear to be due to autoconvective overturning instead of Kelvin-Helmholtz dynamic instability. In other words, mean shear appears to play a relatively minor role in producing the background of clear-air turbulence. Straightforward computations of profiles of refractive index structure function parameter C_n^2 and the rate of dissipation of turbulent kinetic energy, ε, are similar to observations in Colorado but nearly an order of magnitude greater than observations from flatter terrain (which are deemed more relevant to the model parameters). Agreement with the more representative flat terrain values can be obtained either by arbitrarily adjusting the ratio of the turbulence length scale to the layer thickness or by allowing the layers to expand vertically until their Richardson number exceeds the critical value of 0.25 and then by using layer average values for the shear and potential temperature gradient. This model has applicaiton to optical propagation, thermal blooming, clear-air radar performance, extreme shear probability forecasts (e.g., for shuttle launches), the editing of atmospheric data (i.e., when is it likely that a "bad" point is just natural variability?), and the general issue of sampling errors in atmospheric measurements.

WP-032

FAIRALL, C.W., J.E. Hare, and J.B. SNIDER. An eight-month sample of marine stratocumulus cloud fraction, albedo, and integrated liquid water. Journal of Climate 3(8):847-864 (1990).

As part of the First International Satellite Cloud Climatology Regional Experiment (FIRE), a surface meteorology and shortwave/-longwave irradiance station was operated in a marine stratocumulus regime on the northwest tip of San Nicolas Island off the coast of Southern California. Measurements were taken from March through October 1987, including a FIRE Intensive Field Operation (IFO) held in July. Algorithms were developed to use the longwave irradiance data to estimate fractional cloudiness and to use the shortwave irradiance to estimate cloud albedo and integrated cloud liquid water content. Cloud base height is estimated from computations of the lifting condensation level. The algorithms are tested against direct measurements made during the IFO; a 30% adjustment was made to the liquid water parameterization. The algorithms are then applied to the entire database. The stratocumulus clouds over the island are found to have a cloud base height of about 400 m, an integrated liquid water content of 75 g m^{-2}, a fractional cloudiness of 0.95, and an albedo of 0.55. Integrated liquid water content rarely exceeds 350 g m^{-2} and albedo rarely exceeds 0.90 for stratocumulus clouds. Over the summer months, the average cloud fraction shows a maximum at sunrise of 0.74 and a minimum at sunset of 0.41. Over the same period, the average cloud albedo shows a maximum of 0.61 at sunrise and a minimum of 0.31 a few hours after local noon (although the estimate is more uncertain because of the extreme solar zenith angle). The use of joint frequency distributions of fractional cloudiness with solar transmittance or cloud base height to classify cloud types appears to be useful.

WP-033

Fetzer, G.J., and M.J. POST. A low cost CW CO_2 lidar system for low level wind shear detection. Proceedings, Laser Radar V, Los Angeles, CA, 15-19 January 1990. SPIE, Bellingham, WA, 1222:130-141 (1990).

A CW CO_2 lidar system developed to determine the feasibility of using such a system for detecting and measuring low-level wind shear is discussed. The system was constructed from off-the-shelf components at a relatively low cost. Results of preliminary testing of the system are included. Wind shear measurements have been achieved but the capability of the system to measure large-scale microburst-generated wind shear has not been determined at this time.

WP-034

Frehlich, R.G., and J.H. CHURNSIDE. Statistical properties of estimates of the moments of laser scintillation. Journal of Modern Optics36:1645-1659 (1989).

The random fluctuations of laser scintillation are described by the probability density function (PDF) of irradiance. Many models for a general PDF have been proposed, and a common method of analysis has been the comparison of the moments of the PDF with experimental data. The statistical behavior of these estimates for the moments is determined by simulation of actual experimental procedures assuming various models for the true PDF. Realizations for histograms (estimates of the PDF) of digitized data are generated using binomial random deviages. Each realization for the histogram generates a realization for the moments. The PDF of these estimates for the moments is approximated by producing a histogram of a large number of such realizations. These results are compared with recent theoretical predictions. Higher moments are shown to be a poor description of the random process for typical experimental conditions. The effects of

amplifier saturation are also investigated with the same simulations. Saturation becomes important when the median of the maximum irradiance becomes larger than the saturation level.

WP-035

Frehlich, R.G., and G.R. Ochs. Effects of saturation on the optical scintillometer. Applied Optics, 29(4):548-553 (1990).

Measurements of the level of turbulence C_n^2 have been successfully performed with the optical scintillometer. The success of this instrument is based on the observed fact that the variance of aperture averaged scintillation is described by weak scattering theory even for conditions in which strong scintillation is observed for point detectors. However, for sufficiently long propagation paths, the aperture averaged variance is affected by strong scattering. The effects of strong scattering are calculated theoretically and compared to experimental results. The physics of this regime are discussed and the important parameters investigated. The new range of validity of the optical scintillometer is discussed.

WP-036

FRISCH, A.S., B.E. MARTNER, and J.S. GIBSON. Measurement of the vertical flux of turbulent kinetic energy with a single Doppler radar. Boundary-Layer Meteorology 49:331-337 (1990).

The Doppler radar velocity azimuth display (VAD) technique for obtaining first and second moments of radial wind velocities is expanded to third-moment calculations. By scanning at an elevation angle of 50.8°, terms of the third-moment equation can be reduced to yield the vertical flux of turbulent kinetic energy, $\overline{w'q'}$. The technique has been applied to summertime radar measurements of the convective boundary layer in Illinois. Resulting vertical profiles of $\overline{w'q'}$ follow the expected shape, and the magnitudes compare well with those of aircraft measurements in previous studies.

WP-037

FRISCH, A.S., B. STANKOV, B.E. MARTNER, and J.C. KAIMAL. Doppler radar measurements of vertical velocity in the convective boundary layer. Preprints, 9th Conference on Turbulence and Diffusion, Roskilde, Denmark, 30 April-3 May 1990. American Meteorological Society, Boston, MA , 82-85 (1990).

No abstract.

WP-038

FRISCH, A.S., B.L. WEBER, D.B. WUERTZ, R.G. STRAUCH, and D.A. MERRITT. On the maximum of C_n^2 near the tropopause measured with a 50-MHz wind profiler. Meteorologische Rundschau 42:157-161 (1990).

We have analyzed four years of 50 MHz wind profiler data and found that there is a minimum in C_n^2 at about 8 km height. Above 8 km, C_n^2 increases with height to about 12 km, where it is a maximum. There is a seasonal variation in C_n^2 minimum of about 4 dB, and the year-to-year variation is about the same. The C_n^2 maximum does not show a seasonal variation; however, the year-to-year variation is about 7 dB.

WP-039

FRISCH, A.S., B.L. WEBER, D.B. WUERTZ, R.G. STRAUCH, and D.A. MERRITT. The variations of C_n^2 between 4 and 18 km abovesea level as measured over 5 years. Journal of Applied Meteorology 29:645-651 (1990).

We computed the monthly average backscattered power over a five-year period for the Fleming 50 MHz wind profiler, which is proportional to C_n^2. We found that in addition to seasonal cycle in C_n^2 below the tropopause, there was a year-to-year variation as well. Above the tropopause, the seasonal variations were almost gone, however, there were significant changes with periods longer than one year. We examined a shorter backscattered power record from the Stapleton wind profiler and found similar longer-term trends. These long-term trends will affect the performance of wind profilers.

WP-040

Gal-Chen, T., M. Xu, and W.L. EBERHARD. Flux estimation of the FIFE planetary boundary layer (PBL) with 10.6 μm Doppler lidar. Preprints, Symposium on FIFE, Anaheim, CA, 7-9 February 1990. American Meteorological Society, Boston, MA, 51-56 (1990).

No abstract.

WP-041

Gal-Chen, T., M. Xu, and W.L. EBERHARD. Flux estimation of the FIFE planetary boundary layer (PBL) with 10.6 μm Doppler lidar. Proceedings, 9th Symposium on Turbulence and Diffusion, Roskilde, Denmark, 30 April-3 May 1990. American Meteorological Society, Boston, MA, 86-89 (1990).

No abstract.

WP-042

GAYNOR, J.E., C.G. Baker, and J.C. KAIMAL. The international sodar intercomparison experiment. Proceedings, 5th International Symposium on Acoustic Remote Sensing of the Atmosphere and Oceans, New Delhi, India, 6-9 February 1990, Tata McGraw-Hill, New Delhi, India, 67-74 (1990).

The paper presents preliminary results from the International Sodar Intercomparison Experiment (ISIE) conducted at the Boulder Atmospheric Observatory in September 1988. Twenty-minute mean wind speeds and directions from a variety of sodar systems compare well with measurements on the 300-m BAO tower, as they did in an earlier (1982) comparison experiment at the site. The vertical velocity standard deviations compare better than they did before, but the horizontal wind standard deviations showed no improvement.

WP-043

Goldstein, M.K. Converting from VMS to ULTRIX. NOAA TM ERL WPL-176, 20 pp. (1990).

Over the next couple of years, WPL is making the transition from several different operating systems on its various platforms to UNIX, which is fast becoming the computer industry standard. This report records many of the tasks involved in converting from DEC's VMS operating system to ULTRIX on one of WPL's Micro VAXs. It emphasizes the user's perspective and, thus, avoids most of the system-level work. It should, as a result, serve as a handy reference manual for those making the transition from VMS to ULTRIX.

WP-044

Gossard, E.E. Radar research in the atmospheric boundary layer. In Forty Years of Radar Research in the Atmosphere, American Meteorological Society, Boston, MA, 477-527 (1990).

No abstract.

WP-045

Gossard, E.E., and R.G. STRAUCH. The retrieval of dropsize distributions in water clouds from ground-based clear-air-sensing Doppler radar observations. Meteorologische Rundschau 42:165-173 (1990).

The advent of Doppler clear-air radars for wind-height profiling opens the way for their use in a variety of other applications. This paper uses knowledge of the clear-air Doppler spectrum from a zenith-pointing radar together with the measured water droplet Doppler vertical velocity spectrum to calculate spectra of drop number density through clouds of droplets having substantial fall velocity. This report describes procedures that allow spectral lines and other details to be extracted from the radar data. Spectra measured with a 915 MHz, wind-profiling radar are used as examples and compared with the spectra that would have been obtained if the clear-air information were ignored. From the number density vs. dropsize distribution, the corresponding liquid water distribution can be calculated. Failure to take into account turbulence in the medium can result in large errors in number density and liquid water especially in the neighborhood of spectral lines and large gradients. The advantages and limitations of a radar remote sensing drop spectrometer are described.

WP-046

HILL, R.J., S.F. CLIFFORD, R.J. LATAITIS, and A.D. Sarma. Scintillation of millimeter-wave intensity and phase caused by turbulence and precipitation. Proceedings, AGARD 45th Symposium on Atmospheric Propagation in the UV, Visible, IR and mm-wave Region and Related Systems Aspects, Copenhagen, Denmark, 9-13 October 1989. Advisory Group for Aerospace Research and Development, Neuilly-sur-Seine, France, 7:1-6 (1989).

No abstract.

WP-047

HILL, R.J., and R.J. LATAITIS. The effect of refractive dispersion on the bichromatic correlation of irradiance for atmospheric scintillation. Applied Optics 28(19):4121-4125 (1989).

Formulations of the bichromatic correlation of scintillating irradiance are corrected by introducing the cospectrum of the two different refractive indices in place of the refractive index power spectrum. Receiver aperture averaging is included in the formulation. The effect of

dispersion on the bichromatic correlation coefficient is studied and quantified for four specific experimental cases. Dispersion of the water vapor refractive index between wavelengths in the visible and 10 μm window is of particular significance in this study. In most cases, the effect of dispersion on the bichromatic correlation coefficient is much less than on the ratio of monochromatic irradiance correlations, and is negligible for practical considerations. The exception is the case of such strong humidity fluctuations that they (as opposed to temperature fluctuations) cause most of the scintillation of the midinfrared radiation.

WP-048

HILL, R.J., and G.R. Ochs. Optical scintillation instruments for measuring heat and momentum fluxes in the atmospheric surface layer. Proceedings, Topical Meeting on Optical Remote Sensing of the Atmosphere, Incline Village, NV, 12-15 February 1990. Optical Society of America, Washington, DC, 526-527 (1990).

Experimental validation against in-situ instruments shows that optical scintillation techniques are very promising for measuring the atmospheric surface-layer fluxes of heat, momentum, and stability.

WP-049

Huggins, A.W., R.J. Meitin, and R.F. REINKING. Comparison of radiometric measurements of cloud liquid water near a mountain creat and over a downwind valley. Preprints, 5th Conference on Mountain Meteorology, Boulder, CO, 25-29 June 1990. American Meteorological Society, Boston, MA, 135-142 (1990).

No abstract.

WP-050

Intrieri, J.M., A.J. BEDARD, JR., and R.M. HARDESTY. Details of colliding thunderstorm outflows as observed by Doppler lidar. Journal of the Atmospheric Sciences 47(9):1081-1098 (1990).

Three cases of colliding outflow boundaries are examined using data collected from the NOAA Doppler lidar and a meteorological tower during the summer of 1986 near Boulder, Colorado. The data are unique because the lidar and the 300 m tower were collocated, providing measurements of both kinematic and thermodynamic properties. Lidar data reveal small-scale vortex roll instabilities within the leading edge of the outflow. Observations of the post-collision interactions showed that the warmer of the two outflows was deflected upward by the colder outflow to heights of 2 km. In all cases, this forced mechanical lifting was sufficient to produce convection. A simple model of two colliding currents also suggests that deeper outflows are more efficient in initiating convection.

WP-051

Intrieri, J.M., W.L. EBERHARD, and G.L. Stephens. Preliminary comparison of lidar and radar backscatter as a means of assessing cirrus radiative properties. Preprints, 7th Conference on Atmospheric Radiation, San Francisco, CA, 23-27 July 1990. American Meteorological Society, Boston, MA, 354-356 (1990).

No abstract.

WP-052

Intrieri, J.M., C.G. Little, W.J. Shaw, R.M. BANTA, P.A. Durkee, and R.M. HARDESTY. The land/sea breeze experiment (LASBEX). Bulletin of the American Meteorological Society 71:656-664 (1990).

The Land/Sea Breeze Experiment (LASBEX) was conducted at Moss Landing, California, from 15-30 September 1987. The experiment was designed to study the vertical structure and mesoscale variation of the land/sea breeze. A Doppler lidar, a triangular array of three sodars, two sounding systems (one deployed from land and one from a ship), and six surface weather stations (one shipborne) were sited around the Moss Landing area. Measurements obtained included ten sea breeze and four land breeze events. This paper describes the objectives and design of the experiment and the observing systems that were used. Some preliminary results and selected observations are presented of the data collected as well as the ensuing analysis plans.

WP 053

JONES, R.M., T.M. GEORGES, L. Nesbitt, R. Tallamraju, and A.M. Weickmann. Vertical-slice ocean-acoustic tomography—extending Abel inversion to non-axial sources and receivers. Proceedings, 1st French Conference on Acoustics, Lyon, France, 10-13 April 1990. French Acoustic Society, Lyon, France, C2.1013-C2.1016 (1990).

We discuss inversion of vertical-slice ocean-acoustic tomography (travel-time) measurements, in which we use the adiabatic-invariant approximation to convert multi-loop measurements to single-loop ray properties before using an Abel transform. We demonstrate the

inversion by applying it to a simulated pulse-arrival sequence for a uniform sound channel generated by a ray tracing program, and compare the recovered sound-speed profile with that used for the simulation. For a uniform sound channel, the inversion gives both the symmetric and antisymmetric parts of the sound channel, including the vertical displacement of the sound-channel axis.

WP-054

JONES, R.M., T.M. GEORGES, L. Nesbitt, R. Tallamraji, and A.M. Weickmann. Vertical-slice ocean-acoustic tomography inversion—converting multi-l;oop measurements to single-loop data. Proceedings, 5th International Symposium on Acoustic Remote Sensing of the Atmosphere and Oceans, New Delhi, India, 6-9 February 1990. Tata McGraw-Hill, New Delhi, 239-244 (1990).

We discuss inversion of vertical-slice ocean-acoustic tomography (travel-time) measurements, in which we use the adiabatic-invariant approximation to convert multi-loop measurements to single-loop ray properties before using an Abel transform. We demonstrate the inversion by applying it to a simulated pulse-arrival sequence for a uniform sound channel generated by a ray tracing program, and compare the recovered sound-speed profile with that used for the simulation. For a uniform sound channel, the inversion gives both the symmetric and antisymmetric parts of the sound channel, including the vertical displacement of the sound-channel axis.

WP-055

KAIMAL, J.C. Remote atmospheric profiling systems for tropospheric monitoring. NOAA TM ERL WPL-175, 72 pp. (1990).

This report addresses a growing need to replace in situ sounding systems currently used in many tropospheric applications with a mobile remote sensing system using a combination of ground and satellite-based technologies. The performance characteristics of both the proven technologies and the new systems are reviewed to determine how they can be combined effectively. An assessment of cost vs. risk is given and several options for combined systems are proposed.

WP-056

KAIMAL, J.C., and J.E. GAYNOR. Can sodars measure turbulence? 5th International Symposium on Acoustic Remote Sensing of the Atmosphere and Oceans, New Delhi, India, 6-9 February 1990, Tata McGraw-Hill, New Delhi, India, 59-66 (1990).

The paper lists major problems encountered in measuring various turbulence parameters with sodars and reviews recent successes and failures in attempts to measure them. An assessment of the future for such measurements is given.

WP-057

KAIMAL, J.C., and L. Kristensen. Finite sampling, windowing and the estimation of dissipation rates. Preprints, 9th Conference on Turbulence and Diffusion, Roskilde, Denmark, 30 April-3 May 1990. American Meteorological Society, Boston, MA, 25-28 (1990).

No abstract.

WP-058

KING, C.W., P. Gudiksen, and C.A. Russell. Sodar-derived nocturnal drainage flow classifications. Preprints, 5th Conference on Mountain Meteorology, Boulder, CO, 25-29 June 1990. American Meteorological Society, Boston, MA, 244-250 (1990).

No abstract.

WP-059

KING, C.W., and S. Summers. Forecasting winter air quality levels in Denver using discriminant analysis. Preprints, 11th Conference on Probability and Statistics in Atmospheric Sciences, Monterey, CA, 1-5 October 1989. American Meteorological Society, Boston, MA, 161-166 (1989).

No abstract.

WP-060

KROPFLI, R.A., B.W. BARTRAM, and S.Y. Matrosov. The upgraded WPL dual-polarization 8-mm wavelength Doppler radar for microphysical and climate research. Preprints, Conference on Cloud Physics, San Francisco, CA, 23-27 July 1990. American Meteorological Society, Boston, MA, 341-345 (1990).

No abstract.

WP-061

LATAITIS, R.J., S.F. CLIFFORD, and P.T. May. Tropospheric wind profiling using radar "interferometry" (A feasibility study of a compact mobile system). NOAA TM ERL WPL-177, 34 pp. (1990).

We compare the feasibility of using three-beam Doppler, spaced-antenna (SA), and Imaging Doppler Interferometer (IDI) techniques for tropospheric wind profiling at 400 MHz. The SA and IDI methods appear to be the most suited for a compact mobile system because narrow beams and therefore large antennas are not required. The SA technique is a proven technology in the troposphere at 50 MHz. An extension to a 400 MHz system appears to be straightforward. We expect that with the SA method 30-min averages of the wind from 0-10 km can be retrieved with an uncertainty of ±2 m/s. We find the IDI technique for measuring tropospheric winds at 400 MHz to be a particularly promising though yet unproven technology. Advantages include a potential capability of high resolution imaging of the wind field in the radar volume not attainable by the SA method. Disadvantages include the necessity for having several highly localized and persistent scattering centers in the volume, and the inherently low effective signal-to-noise ratios associated with the shorter dwell times needed to locate the scatterers, which results in higher power requirements. The ability of the IDI to detect these scatterers at 400 MHz in the troposphere has not been tested. Under ideal conditions, we expect uncertainties in the IDI wind estimates to be comparable to those obtained with the SA technique.

WP-062

LATAITIS, R.J., G.B. Crawford, and S.F. CLIFFORD. A simple low-frequency acoustic technique for remote measurement of the temporal ocean wave spectrum. Journal of the Acoustical Society of America 87:111-118 (1990).

A theory is presented that describes a method for using low-frequency sound ($\lesssim$ 150 Hz) to measure the waveheight variance and the nondirectional temporal waveheight spectrum of a random rough surface such as the sea surface. The technique requires a vertically pointing broadbeam acoustic source and a colocated broadbeam receiver which records the amplitude and phase fluctuations of the backscattered field. When the rms surface waveheight is much smaller than the acoustic wavelength, the temporal spectrum of the amplitude and phase fluctuations can be directly related to the nondirectional temporal surface waveheight spectrum. The theory predicts that the temporal waveheight spectrum out to frequencies of roughly 0.5 Hz can be retrieved.

WP-063

Liu, A.K., F.C. Jackson, and E.J. Walsh. A case study of wave-current interaction near an oceanic front. Journal of Geophysical Research 94:16189-16200 (1989).

High resolution directional wave spectrum data were obtained from two NASA airborne radars during the Frontal Air-Sea Interaction Experiment (FASINEX) in February 1986. The observations show a significant change in the wave number spectrum across the front. On the basis of surveys from a towed sensor and on satellite imagery, the front location and current field are estimated. A numerical model is developed for the wave-current interaction and is used to model the wave refraction across the frontal current. A parametric study is performed to demonstrate the effects of current meandering. The main consequence of meandering is the formation of caustics and shadow zone regions in which the wave energy is significantly enhanced or reduced. Spectral simulation along the aircraft track reveals a reduction of more than 60% in wave energy in the shadow zone; this is consistent with the observations.

WP-064

MARTNER, B.E. Radar observations of transport and diffusion of chaff in a stratus cloud. Preprints, 9th Symposium on Turbulence and Diffusion, Roskilde, Denmark, 30 April-3 May 1990. American Meteorological Society, Boston, MA, 115-118 (1990).

A dual-polarization radar was used to detect the location and concentration of microwave chaff fibers released in a stratiform cloud. The radar tracked the cloud and the chaff within it for more than half an hour. Measurements of the temporal changes of chaff concentration by the radar allowed the cloud's diffusion characteristics to be examined. Three-dimensional perspective views of the chaff location and concentrations are presented.

WP-065

MARTNER, B.E., and R.A. KROPFLI. TRACIR: A radar technique for observing the exchange of air between clouds and their environment. Atmospheric Environment 23:2715-2721 (1989).

Dual-polarization radar measurements can be used to track parcels of air filled with aluminized chaff as they move into and through clouds, as well as in clear air. The circular depolarization ratio (CDR) signal of backscatter from chaff fibers is much stronger than that of most hydrometeors. The difference can be used to detect the location of chaff within clouds when conventional single-polarization radar methods fail. The new technique is called TRACIR (TRacking Air with CIrcular-polarization Radar). Field tests and analytic studies indicate the technique can be useful in studying how effectively clouds entrain dry air and vent pollutants out of the planetary boundary layer.

WP-066

MARTNER, B.E., and J.D. Marwitz. Transport and diffusion of chaff in a convective cloud. Preprints, Conference on Cloud Physics, San Francisco, CA, 23-27 July 1990. American Meteorological Society, Boston, MA, 722-729 (1990).

No abstract.

WP-067

May, P.T., K.P. MORAN, and R.G. STRAUCH. The accuracy of RASS temperature measurements. Journal of Applied Meteorology 28(12):1329-1335 (1989).

Temperature measurements obtained using radiosondes and Radio Acoustic Sounding System (RASS) are compared to assess the utility of the RASS technique for meteorological studies. The agreement is generally excellent; rms temperature differences are about 1.0°C for comparisons during a variety of meteorological conditions. Observations taken under ideal circumstances indicate that a precision of about 0.2°C is achievable with the RASS technique. A processor being designed for RASS should allow routine temperature measurements approaching this precision.

WP-068

May, P.T., R.G. STRAUCH, K.P. MORAN, and W.L. ECKLUND. Temperature sounding by RASS with wind profiler radars: a preliminary study. IEEE Transactions on Geoscience and Remote Sensing 28(1):19-28 (1990).

RASS (Radio Acoustic Sounding System) is a method of remotely measuring atmospheric temperature profiles by combining acoustic and radar techniques. This method has been applied to wind profiler radars in Colorado, and excellent performance in both height coverage and accuracy has been obtained. Various acoustic source functions are examined, and it is shown that FM-CW acoustic signals are less susceptible to error than pulsed acoustic systems when using pulsed radars for RASS. The remotely determined temperature profiles are compared with colocated radiosonde soundings and good agreement is found.

WP-069

May, P.T., R.G. STRAUCH, K.P. MORAN, B.L. WEBER, D.B. WUERTZ, and D.A. MERRITT. Applications of RASS with wind profiler radars. Proceedings, IGARSS '90, College Park, MD, 20-24 May 1990. IEEE, New York, NY, 1177-1178 (1990).

No abstract.

WP-070

MORAN, K.P., D.B. WUERTZ, R.G. STRAUCH, N.L. ABSHIRE, and D.C. LAW. RASS demonstration on a NOAA network wind profiler. NOAA TM ERL WPL-184, 22 pp. (1990).

The National Oceanic and Atmospheric Administration (NOAA) is constructing a wind profiler network in the central United States to evaluate the utility of nearly continuous wind data and, in particular, its effect on short-term weather forecasting. The UHF (404.37 MHz) radars can also measure vertical profiles of virtual temperature in the lower troposphere by the Radio Acoustic Sounding System (RASS) technique. Vertical temperature data are obtained with the same spatial and temporal resolution that are used for wind profiling. A series of tests was conducted in April and May 1990 to obtain a preliminary evaluation of how well RASS would operate with the new wind profilers for the NOAA network. The network prototype radar, located at Platteville, Colorado, was used to collect RASS data. RASS data from two other profilers were available for comparison. Height coverage of the RASS data began at 500 m above the surface and extended to 3.5-5.2 km with the NOAA network profiler.

WP-071

Minnis, P., P. Heck, D. Young, C.W. FAIRALL, and J.B. SNIDER. Comparison of stratocumulus cloud properties derived from simultaneous satellite and surface-based instrumentation. Preprints, Conference on Cloud Physics, San Francisco, CA, 23-27 July 1990. American Meteorological Society, Boston, MA, 159-166 (1990).

No abstract.

WP-072

Mueller, P.K., R.C. Henry, W.E. Balson, L.W. Richards, M. Pitchford, J.G. Watson, W.D. NEFF, P. Saxena, and W.E. Wilson. Future research on visibility and fine particles: Report from a panel discussion. In Transactions: Visibility and Fine Particles, C.V. Mathai, (ed.), Air and Waste Management Association, Pittsburgh, PA, 972-989 (1990).

Important advances and critical limitations deserving further research identified in the course of this conference are discussed. Determining the influence of atmospheric emissions on visibility requires a theoretical and observational understanding of the relationships between emissions and aerosols, aerosols and atmospheric optics, optics and human perception, and human perception and economic valuation. The panel concluded that: objective human observation of vista qualities is now practical but needs more testing; valuation methods remain underdeveloped in concept and controversial in application; methods remain to be adopted to account for path radiance; photographic simulations of vistas need improvement; available methods should be standardized; sampling problems for aerosol components existing simultaneously in the gas and particle phases can now be eliminated; composition of individual particles deserves more study utilizing newly available technology; receptor modeling of secondary aerosols needs further development; new radar and lidar technology is ready for unattended, continuous atmospheric profiling; and capabilities for reliably simulating emission options via interactive applications of receptor and comprehensive deterministic models are expected to be practical within two or three years.

WP-073

NEFF, W.D. Remote sensing of atmospheric processes over complex terrain. In Current Directions in Atmospheric Processes over Complex Terrain, (Chapter 8). Meteorological Monograph. American Meteorological Society, Boston, MA, 173-228 (1990).

This chapter describes the application of a variety of remote sensors to complex terrain studies, including sodars, lidars (aerosol mapping and Doppler), clear-air radars and wind profilers, and optical crosswind sensors. It outlines sensor characteristics relevant to operation in complex terrain settings and examines the origin of turbulence microstructure in complex terrain flows, a significant factor in the use of clear-air radars and sodars. It also summarizes the major programs that have made extensive use of remote sensors and promoted their integration with conventional in situ instruments. Examples and case studies from these programs are then provided, including observations of the initiation and destruction of drainage winds. The behavior of quasi-steady drainage winds and their irregularities during marine layer intrusions, seiches, waves, and strong ambient winds are also described. Recent results are presented that extend the use of Doppler lidar in channeled and merging valley flows as well as in the observation of large-scale mountain-plain circulations. The integration of remote and in situ sensors in a major transport and dispersion study yields further examples of how different measurement methods can complement each other. Future directions in the study of complex terrain processes are suggested that can take advantage of newly developing remote sensors especially in application to larger-scale mountain-valley circulations.

WP-074

NEFF, W.D., W.L. EBERHARD, and C.W. KING. Remote sensor observations of thermally and dynamically driven circulations in the South Platte River basin. Preprints, 5th Conference on Mountain Meteorology, Boulder, CO, 25-29 June 1990. American Meteorological Society, Boston, MA, 42-49 (1990).

No abstract.

WP-075

NEFF, W.D., and C.W. KING. The use of sodars in an urban air quality study. Proceedings, 5th International Symposium on Acoustic Remote Sensing of the Atmosphere and Oceans, New Delhi, India, 6-9 February 1990. Tata McGraw-Hill, New Delhi, India, 506-512 (1990).

This paper describes two uses of sodars in an urban air quality study. One high-frequency sodar was used in a dense urban area to monitor inversion formation due to shadowing of tall buildings. A second monostatic/Doppler sodar installation provided stability/transport classifications for stratifying chemical species concentrations.

WP-076

NEFF, W.D., and D. Ruffieux. The effect of radiative flux divergence and cross-winds on the initiation and structure of nocturnal drainage flows. Preprints 5th Conference on Mountain Meteorology, Boulder, CO, 25-29 June 1990. American Meteorological Society, Boston, MA, 260-265 (1990).

No abstract.

WP-077

NEFF, W.D., and D. Ruffieux. A model study of entrainment by accelerating ambient winds of stably stratified nocturnal drainage flows and cold-air pools. Preprints, 5th Conference on Mountain Meteorology, Boulder, CO, 25-29 June 1990. American Meteorological Society, Boston, MA, 289-295 (1990).

No abstract.

WP-078

NEFF, W.D., and J. Watson. Evaluation of the fuel-switching strategy used in the Denver Brown Cloud study. In Transactions: Visibilityand Fine Particles, C.V. Mathai (ed.), Air and Waste Management Association, Pittsburgh, PA, 410-421 (1990).

A significant feature of the 1987-1988 Denver Brown Cloud Study was the switching of fuel in Denver's power plants from coal to natural gas at about 2-week intervals. On the average the study did not detect an expected reduction in sulfate during gas burning periods, despite an expected 70% reduction in sulfur dioxide, its precursor. This paper presents analyses indicating that under certain meteorological situations, sources far from the Denver area may contribute sufficient sulfate through long-range transport to complicate the interpretation of observations in Denver, particularly when considering average concentrations. The results also indicate that emission-modulation strategies such as those used in Denver may be dominated by meteorological variability unless a sufficiently long time series can be obtained to provide a representative and statistically valid sample. Furthermore, once the influence of long-range transport from distant sources is eliminated, the data reveal more clearly the role of ground-based sources in the formaiton of secondary particles.

WP-079

NEIMAN, P.J., P.T. May, M.A. SHAPIRO, and B.B. STANKOV. RASS observations of an Arctic front in Colorado. Proceedings, Topical Meeting on Optical Remote Sensing of the Atmosphere, Incline Village, NV, 12-15 February 1990. Optical Society of America, Washington, DC, 632-635 (1990).

No abstract.

WP-080

NEIMAN, P.J., and M.A. SHAPIRO. Research aircraft measurements of an intense marine cyclone. Proceedings, 4th Conference on Mesoscale Processes, Boulder, CO, 25-29 June 1990. American Meteorological Society, Boston, MA, 3-4 (1990).

No abstract.

WP-081

NEIMAN, P.J., M.A. SHAPIRO, E.G. DONALL, and C.W. Kreitzberg. Diabatic modification of an extratropical marine cyclone warm sector by cold underlying water. Monthly Weather Review 118(8):1576-1590 (1990).

On 25-27 January 1988, the National Oceanic and Atmospheric Administration's Wave Propagation Laboratory, Drexel University, and the Office of Naval Research carried out a combined pre-ERICA research aircraft investigation of a major marine cyclone moving northeastward over the Canadian Maritime Provinces. Flight-level and dropwindsonde observations documented the diabatic modification of the cyclone's warm sector marine boundary layer (MBL) as it moved out over cold underlying water. These observations and results from the Blackadar one-dimensional boundary layer model both show that heat fluxes were directed downward from the warm sector MBL into the cold ocean. Vertical gradients of these downward heat fluxes diabatically cooled the lower portion of the warm sector MBL and generated large static stability within the entire layer. The increase in stable stratification allowed large vertical wind shear to exist within this layer and strong wind speeds to exist at its top. The increase in static stability within the warm sector MBL acted to concentrate isentropic potential vorticity in this layer, but these changes also weakened the horizontal gradients of temperature, moisture, and wind velocity within the adjacent warm-and cold-frontal zones at the surface.

WP-082

Ochs, G.R., J.K. HOLLER, and J.J. WILSON. An optical inner scale meter. NOAA TM ERL WPL-183, 18 pp. (1990).

This report describes an optical instrument that measures the path-averaged value of the inner scale of refractive-index turbulence over a range of 2-30 mm, and is optimized for 150-m propagation path lengths. Operating procedures are also described that include the description and use of an external calibrator.

WP-083

Palmer, A.J. Non-linear remote sensing opportunities in the atmosphere. Proceedings, Topical Meeting on Optical Remote Sensing of the Atmosphere, Incline Village, NV, 12-15 February 1990. Optical Society of America, Washington, DC, 301-304 (1990).

No abstract.

WP-084

Palmer, D.R., T.M. GEORGES, and R.M. JONES. Chaos in underwater acoustics. Proceedings, 5th International Symposium on Acoustic Remote Sensing of the Atmosphere and Oceans, New Delhi, India, 6-9 February 1990. Tata McGraw-Hill, New Delhi, India, 210-215 (1990).

During numerical simulations of acoustic propagation in a weakly range-dependent, deterministic ocean, we find conditions that produce chaotic ray paths. Chaos is an instability which results from the nonlinear nature of the differential equations which determine the ray paths, rather than from externally imposed noise or randomness. It places a fundamental limitation on the range to which an acoustic field can be predicted. We also discuss some new methods for identifying chaotic rays which have advantages over the standard methods. Finally, we note the existence of chaotic rays for propagation in the Straits of Florida.

WP-085

Palmer, D.R., T.M. GEORGES, and R.M. JONES. Chaotic ray paths in underwater acoustics. Proceedings, 1st French Conference on Acoustics, Lyon, France, 10-13 April 1990. French Acoustic Society, Lyon, France, C2.965-C2.968 (1990).

We simulate and explore the properties of chaotic ray paths in a weakly range-dependent, deterministic ocean. Chaos results from nonlinearity of the differential equations that determine the ray paths, rather than from randomness in the model of the medium or from externally imposed noise. Extreme sensitivity to model details and initial ray conditions places a practical limit on the predictability of acoustic field properties, such as travel time. Chaotic ray paths are identified using the traditional Poincare section, power spectra and exponential sensitivity to initial conditions. We also discuss new diagnostic techniques that have some advantages over the traditional ones.

WP-086

Parsons, D.B., and R.A. KROPFLI. Dynamics and fine structure of a microburst. Journal of the Atmospheric Sciences 47(13):1674-1692 (1990).

Details of the structure of a moderate reflectivity microburst were provided by dual-Doppler radar measurements during the Phoenix II convective boundary layer experiment. The data set allowed high resolution of the descending microburst in both time and space. Thermodynamic fields of virtual potential temperature and buoyancy retrieved from the radar measurements indicated that the downdraft was associated with potentially cooler and negatively buoyant air, rather than coinciding with a maximum in precipitation loading. The physical separation of the downdraft from the reflectivity maxiumum was especially well pronounced during the later stages of the microburst and was partly due to the tilted reflectivity core descending more rapidly than the downdraft. These findings suggest that the negative buoyancy associated with the microburst in the boundary layer was dominated by evaporative cooling and melting rather than by precipitation loading. Downdrafts and cores of negatively buoyant air descended at a rate slower than the magnitude of the maximum downdraft; air was continually converging and entraining into the downdraft above the level of its peak value and was detraining and diverging below it. Observation and recognition of this circulation may provide an important precursor to microburst activity. The retrieved pressure fields showed that this slower descent and associated internal circulation was due, in part, to an upward-directed pressure force. Simple calculations suggest that this influence of the pressure force on the vertical accelerations depends strongly on the aspect ratio of the negatively buoyant parcel; horizontally narrow and vertically deep negatively buoyant parcels result in stronger downdrafts than wider and shallower parcels. Our study suggests the internal circulation and the relatively slow descent of the peak down draft should be inherent characteristics of microbursts driven by cores of low virtual potential temperature air, while microbursts driven primarily by water loading could be expected to have a different structure. In the case of the microbursts driven by cores of cool air, observation and recognition of the convergence and divergence associated with the internal circulation provide important precursors to microburst activity. In this study, the Coppler measurements showed that the microburst descending into a stable layer may have enhanced the divergence pattern below the peak downdraft.

WP-087

Parsons, C.L., and E.J. Walsh. Beam-limited radar altimetry. Proceedings, IGARSS '90, College Park, MD, 20-24 May 1990. IEEE, New York, NY, 1435-1438 (1990).

The Multimode Airborne Radar Altimeter (MARA) has been developed at NASA's Goddard Space Flight Center to investigate beam-limited precision radar altimetry. Acceptable beam-limited altimetry performance will be required at off-nadir incidence angles to achieve wide-swath topographic mapping, a future remote sensing goal for the earth sciences. MARA was installed on the Wallops Flight Facility P-3 research aircraft in November 1989 and engineering test flights and local experimental missions have been conducted with the instrument in its five-beam, fixed-beam mode. Preliminary results are presented in this paper.

WP-088

Pearson, G.N., B.J. Rye, and R.M. HARDESTY. Design of a high pulse repetition rate CO_2 Doppler lidar for atmospheric monitoring. Proceedings, High Power Lasers and Optical Computing Conference, Los Angeles, CA, 14-19 January 1990. SPIE, Bellingham, WA, 1222:142-153 (1990).

The operating requirements for infrared coherent lidars utilizing tropospheric backscatter are reviewed briefly, and a design for an improved CO_2 laser source, based on recent developments in the technology, is proposed that meets these requirements and is compact and capable of unattended operation.

WP-089

POST, M.J., A.M. Weickmann, and G.T. McNice. Recent profiles of atmospheric backscatter. Proceedings, Topical Meeting on Optical Remote Sensing of the Atmosphere, Incline Village, NV, 12-15 February 1990. Optical Society of America, Washington, DC, 316-319 (1990).

No abstract.

WP-090

REINKING, R.F., R.A. KROPFLI, B.E. MARTNER, and R. Caiazza. Initial findings from the Lake Ontario Winter Storms (LOWS) experiment. Preprints, 4th Conference on Mesoscale Processes, Boulder, CO, 25-29 June 1990. American Meteorological Society, Boston, MA, 134-137 (1990).

No abstract.

WP-091

REINKING, R.F., R.A. KROPFLI, B.E. MARTNER, J.B. SNIDER, and R.J. ZAMORA. Lake Ontario Winter Storms Project—Inventory of data from NOAA Wave Propagation Laboratory instrumentation. NOAA TM ERL WPL-181, 108 pp. (1990).

Banded snowstorms generated over Lake Ontario frequently produce localized but extremely heavy precipitation and blizzard conditions including whiteouts inland from the leeside shores. Also on a mesoscale, hazardous freezing rain frequently impacts the same region in winter. A consortium of scientists from the government, universities and private industry, led by NOAA's Wave Propagation Laboratory, conducted the field phase of the Lake Ontario Winter Storms (LOWS) Project in the Lake Ontario basin between 5 January and 1 March 1990 to study these severe weather phenomena. The project focused on providing the specialized instrumentation and knowledge for making accurate 0-12 h forecasts of the severe but shallow lake-effect storms and subsynoptic aspects of freezing rain, which are not routinely resolved or observed with standard meteorological tools. LOWS is an exercise in basic weather science and in the demonstration and transfer of new remote sensing technologies developed at the NOAA Wave Propagation Laboratory (WPL) to a private industry, the Niagara Mohawk Power Corporation (the primary sponsor of LOWS), and to other potential users, including the National Weather Service. This report is an inventory of the data collected with NOAA/WPL instrumentation used in LOWS: an X-band, dual-polarization, Doppler radar; a three-channel, steerable microwave radiometer; and a 915 MHz wind profiling radar. Inventories of data collected by the other organizations of the consortium will be published in parallel reports.

AP-092

REINKING, R.F., and R.J. Meitin. Recent progress and needs in obtaining physical evidence for weather modification potentials and effects. Journal of Weather Modification, 21:85-93 (1989).

Statistical and numerical modeling approaches to assess the effects of cloud seeding require the interactive input of, and understanding derived from, measurements that provide direct evidence of natural and altered development of precipitation.
A brief review of recent progress in obtaining physical evidence to evaluate and verify potentials for and effects of precipitation enhancement and hail suppression is presented. Recent findings from the National Oceanic and Atmospheric Administration's Federal/State Cooperative Program in Weather Modification Research are emphasized, but other related results are included. In the context of many significant new advances toward proving hypotheses by direct measurement, a number of remaining needs for measurements and corresponding technologies are identified.

WP-093

REINKING, R.F., J.L. Stith, and R.J. Meitin. Airborne Doppler radar and in situ studies of the transport of ozone and other constituents in feeder cells and anvils. Preprints, Conference on Cloud Physics, San Francisco, CA, 23-27 July 1990. American Meteorological Society, Boston, MA, 698-705 (1990).

No abstract.

WP-094

Ruffieux, D. Evoluation of the surface energy budget in complex terrain and its effect on the initiation of an inversion layer near the ground. Preprints, 5th Conference on Mountain Meteorology, Boulder, CO, 25-29 June, 1990. American Meteorological Society, Boston, MA, 255-259 (1990).

No abstract.

WP-095

Rye, B.J. Kalman filtering in lidar. 5th Conference on Coherent Laser Radar: Technology and Applications, Munich, FRG, 5-9 June 1989. SPIE, Bellingham, WA, 1181:202-209 (1989).

A processing strategy for lidar signals based on established concepts of Kalman filtering is described. Features of relevance to lidar include use of stochastic and non-stationary system models, the need for non-linear and multi-dimensional models in many applications, and the ability to "self-tune" the filter in response to data input in the absence of *a priori* information.

WP-096

Sassen, K., A. W. Huggins, A. B. Long, J. B. SNIDER, and R. Meitin. Investigations of a winter mountain storm in Utah, Part II: mesoscale structure, supercooled liquid water development and precipitation processes. Journal of the Atmospheric Sciences 47:1323-1350(1990).

A comprehensive analysis of a deep winter storm system during its passage over the Tushar Mountains of southwestern Utah is reported. The case study, drawn from the 1985 Utah/NOAA cooperative weather modification experiment, is divided into descriptions of the synoptic and kinematic properties in Part I, and storm structure and composition here in Part II. In future parts of this series, the turbulence structure and indicated cloud seeding potential will be evaluated. The analysis presented here in Part II focused on multiple remote sensor and surface microphysical observations collected from a midbarrier (2.57 km MSL) field site. The collocated remote sensors were a dual-channel microwave radiometer, a polarization lidar, and a K_a-band Doppler radar. These data are supplemented by upwind-valley-based C-band Doppler radar observations, which provided a considerably larger-scale view of the storm.

WP-097

SCHROEDER, J.A. A comparison of temperature soundings obtained from simultaneous radiometric, radio-acoustic, and rawinsonde measurements. Journal of Atmospheric and Oceanic Technology 7(3):495-503 (1990).

Atmospheric temperature soundings retrieved from a radio-acoustic sounding system (RASS), a six-channel microwave radiometer system, and a combined RASS/radiometer system during two seasons at Denver, Colorado, are compared. The retrieval technique employed, which operationally produces temperature soundings from the radiometer measurements, extends the RASS altitude coverage and provides a simple way to combine RASS and radiometer measurements. Accuracy is evaluated by comparing the retrieved soundings with colocated rawinsonde soundings. Little difference in accuracy among systems is observed during summer, but the winter dataset, characterized by strong low-level temperature inversions, demonstrates the superior vertical resolution of RASS within its measurement altitude range. At higher altitudes, the quality of temperature soundings retrieved from RASS alone are comparable to those of the radiometer alone. Some improvement in accuracy results from combining RASS and radiometer information.

WP-098

SCHROEDER, J.A., J.R. JORDAN, and M.T. Decker. Design considerations for a network of thermodynamic profilers. Journal of Atmospheric and Oceanic Technology 6:840-845 (1989).

A modular design for a ground-based thermodynamic profiler is presented, based on experience with a six-channel microwave radiometer that has provided temperature, pressure, and moisture measurements continuously, unattended, since 1981. Each module consists of one pair of microwave channels, whose frequencies are chosen to facilitate the joint use of radio-frequency (RF) components, thus reducing hardware costs by nearly half. The number of modules included in a given system can be chosen to suit the altitude and accuracy requirements for that particular application. The accuracy of temperature and pressure heights retrieved from simulated profilers with 4 to 18 channels is presented to illustrate the tradeoff between cost and accuracy.

WP-099

SCHROEDER, J.A., E. R. WESTWATER, L.M. McMillin, and P.T. May. Remote temperature sounding by inverse covariance weighting of soundings from TOVS and ground-based RASS and radiometer systems. Proceedings, IGARSS '90, College Park, MD, 20-24 May 1990. IEEE, New York, NY, 1189-1191 (1990).

No abstract.

WP-100

Shang, E.C. An efficient high-resolution method of source localization processing in mode space. Journal of the Acoustical Society of America 86(5):1960-1964 (1989).

The matched-field processing proposed by Bucker [J. Acoust. Soc. Am. 59, 368-373 (1976)] can be performed in phone space (matching the total field received by each phone of an array) or in mode space (matching a subset of modes resolved from the array data). For a stratified waveguide, processing in mode space can be more efficient and more robust. However, the method processing in mode space previously proposed as the "modal beamforming" method has the drawback of less inherent resolution. In this paper, the high-resolution model matching (HRMM) method has been proposed instead of the "modal beamforming" technique. One of the advantages of the HRMM method is that high resolution can be achieved even when only a few modes are available; for depth estimation especially, the first two modes are good enough. Some numerical examples are presented.

WP-101

Shang, E.C., Y.Y. Wang, H.Y. Chen, and I.T. Lu. Acoustic source localization in a wedge-shaped shallow water waveguide. In Computational Acoustics, Vol. 3, Lee, Cakmak, and Vichnevetaky (eds.), Elsevier Science Publishers, New York, 237-245 (1990).

Acoustic source localization schemes in a two-dimensional wedge-shaped shallow water waveguide are presented. The field data along a vertical receiving array are generated by using the PE (IFD) code for both down-slope and up-slope propagations. These data are processed by the Adiabatic Mode Filtering (AMF) approach. The range and depth information can be extracted from the adiabatic modal phase differences and the modal amplitude ratios, respectively. A least square matching scheme is proposed. Numerical simulations illustrate that the AMF approach can provide satisfactory results up to the wedge angle -1 deg in an appropriate frequency band.

WP-102

SHAPIRO, M.A. Revising the Norwegian frontal-cyclone model. Proceedings, Conference on the 40th Anniversary of the Dept. of Meteorology of Florida State University, Tallahassee, FL, 30 November-1 December 1989. Florida State University, Tallahassee, FL, 31-34 (1989).

No abstract.

WP-103

SHAPIRO, M.A., E.G. DONALL, P.J. NEIMAN, and L.S. FEDOR. On the mesoscale structure of extratropical marine cyclones. Preprints, 4th Conference on Mesoscale Processes, Boulder, CO, 25-29 June 1990. American Meteorological Society, Boston, MA, 1-2 (1990).

No abstract.

WP-104

SHAPIRO, M.A., and L.S. FEDOR. A case study of an ice-edge boundary layer front and polar low development over the Norwegian and Barents Seas. In Polar and Arctic Lows. Twitchell, Rasmussen and Davidson (eds.), A. Deepak Publishing, Hampton, VA, 257-277 (1989).

This study presents the analysis of the structure of selected mesoscale weather systems observed over the Norwegian and Barents Seas during the Arctic Cyclone Expedition, 1984. Observations taken with the NOAA P-3 research aircraft and its dropwindsonde system, high-resolution AVHRR images from the polar orbiter satellites, and conventional surface and upper air stations were used to describe an ice-edge boundary layer front and associated jet stream along the west coast of Spitsbergen, an arctic cold-air outbreak and arctic cold front, and the development of two polar lows. Results show that the ice-edge front and jet formed in response to horizontal gradients in sensible heating as cold air (~ -20°C) flowed off the arctic ice pack over the warm (0°C) underlying ocean along the west coast of ice-snow-covered Spitsbergen. Polar low development occurred within the shallow (~ 1 km) frontal baroclinicity at the leading edge of the arctic cold-air outbreak.

WP-105

SHAPIRO, M.A., T. HAMPEL, and L.S. FEDOR. Research aircraft observations of an Arctic front over the Barents Sea. In Polar and Arctic Lows. Twitchell, Rasmussen and Davidson (eds.), A. Deepak Publishing, Hampton, VA, 279-289 (1989).

Research aircraft flight-level and dropwindsonde observations documented the structure of an arctic front that formed over the Barents Sea south of Spitsbergen and the Arctic Sea ice pack. The front formed in the confluence of warm southwesterly open ocean flow and cold northeasterly off-ice flow. The front was extremely shallow in slope, not extending above 800 mb in the 400-km extent of its observation. Analyses of front-normal and parallel wind components were used to diagnose the vorticity and divergence fields for the front. Airborne

weather radar observations document a mesoscale (~ 100 km) precipitation feature that formed within the cyclonic vorticity and convergence of the leading edge of the frontal zone.

WP-106

SHAPIRO, M.A., and D. Keyser. Fronts, jet streams, and the tropopause. NOAA TM ERL WPL-182, 75 pp. (1990).

This report reviews past and present interpretations that have arisen regarding the structure and governing dynamics of fronts, jet streams, the tropopause, and the life cycle of the marine extratropical cyclone and its fronts. It is shown that new insights and the resolution of previous controversies have been linked, in part, to technological advances in atmospheric observing systems and, more recently, to the use of computers for diagnosis and numerical simulation.

WP-107

Smith, W.L., H.E. Revercomb, H.B. Howell, H.M. Woolf, R.O. Knuteson, R.G. Decker, M.J. Lynch, E.R. WESTWATER, R.G STRAUCH, K.P. MORAN, B. STANKOV, M.J. FALLS, J. JORDAN, M.D. JACOBSON, W.F. Dabberdt, R. McBeth, G. Albright, C. Paneitz, G. Wright, P.T. May, and M.T. Decker. GAPEX: A Ground-based Atmospheric Profiling EXperiment. Bulletin of the American Meteorological Society 71:310-318 (1990).

During the week 29 October-4 November 1988, a Ground-based Atmospheric Profiling Experiment (GAPEX) was conducted at Denver Stapleton International Airport. The objective of GAPEX was to acquire and analyze atmospheric-temperature and moisture-profile data from state-of-the-art remote sensors. The sensors included a six-spectral-channel, passive Microwave Profiler (MWP), a passive, infrared High-Resolution Interferometer Sounder (HIS) that provides more than 1500 spectral channels, and an active Radio Acoustic Sounding System (RASS). A Cross-Chain Loran Atmospheric Sounding System (CLASS) was used to provide research-quality in situ thermodynamic observations to verify the accuracy and resolution characteristics of each of the three remote sensors. The first results of the project are presented here to inform the meteorological community of the progress achieved during the GAPEX field phase. These results also serve to demonstrate the excellent prospects for an accurate, continuous thermodynamic profiling system to complement NOAA's forthcoming operational wind profiler.

WP-108

STANKOV, B.B., and A.J. BEDARD, JR. Atmospheric conditions producing aircraft icing on 24-25 January 1989: A case study utilizing combinations of surface and remote sensors. Preprints, 28th Aerospace Sciences Meeting, Reno, NV, 8-11 January 1990. American Institute of Aeronautics and Astronautics, Washington, DC (1990).

An array of remote sensing instruments and *in situ* instruments were used to study aircraft icing conditions during the winter storm on 24-25 January 1989 in Colorado. For adequate meteorological characterization of the observed aircraft icing event, it was found to be necessary to have continuous measurements of cloud liquid water, continuous measurements with high vertical resolution of temperature, and measurements of the height of cloud base and cloud top. Present and future remote sensing capabilities for the detection of aircraft icing events are described.

WP-109

Stith, J.L., A.G. Detwiler, R.F. REINKING, and P.L. Smith. Investigating transport, mixing and the formation of ice in cumuli with gaseous tracer techniques. Atmospheric Research 25:195-216 (1990).

Applications of tracer techniques, using insoluble sulfur hexafluoride (SF_6) to studies of transport, mixing and the activation of silver iodide aerosols in cumuli are presented. One cumulus was treated with SF_6 and the aerosol near the cloud top, in a region of little vertical transport. Up to 24% of the potential nuclei produced measurable ice particles 7 min after treatment, in accord with the results of recent laboratory measurements of activation of this aerosol via contact nucleation. A second cumulus was treated at the cloud base with SF_6 and the aerosol. The materials were transported to and mixed through the upper regions of the cloud. Ice particles evidently formed near the cloud top (estimated cloud top temperature -13°C); the nucleation cannot be positively attributed to the silver iodide in this case, but the ice particle concentrations in the upper part of the cloud and in downdrafts at lower levels were consistent with the concentrations of AgI nuclei estimated from the tracer measurements. At lower levels of the cloud the materials were not so well mixed, the most concentrated regions being found on the upshear side of the cloud and dilute regions downshear. Mid- and upper-level ice concentrations were greatest in downdrafts on the downshear side, suggesting that the downdraft was important in transporting the ice to lower levels of the cloud.

WP-110

STRAUCH, R.G., P.T. May, K.P. MORAN, D.A. MERRITT, and W.L. ECKLUND. Advances in RASS. Proceedings, 5th International Seminar on Acoustic Remote Sensing, New Delhi, India, 6-9 February 1990. Tata-McGraw Hill, New Delhi, India, 97-108 (1990).

No abstract.

WP-111

STRAUCH, R.G., D.A. MERRITT, K.P. MORAN, B.L. WEBER, D.B. WUERTZ, and P.T. May. Wind profilers for support of flight operations. Journal of Aircraft 26(11):1009-1015 (1989).

Wind profilers are becoming an accepted component of meteorological observing systems. This paper discusses various types of wind profilers, illustrates their capabilities and the data they can provide to support flight operations, and discusses their limitations. In addition the wind profiler has revived the radio-acoustic sounding system (RASS) technique for measuring temperatures. Preliminary RASS results are presented to demonstrate that wind profilers may also provide temperature measurements in the lowest part of the atmosphere; this capability substantially enhances their value for weather forecast services.

WP-112

UTTAL, T., R.A. KROPFLI, W.L. EBERHARD, and J.M. Intrieri. Observations of mid-latitude continental cirrus clouds using a 3.2 cm radar: Comparisons with 10.6 micron lidar observations. Proceedings, 7th Conference on Atmospheric Radiation, San Francisco, CA, 23-27 July 1990. American Meteorological Society, Boston, MA, 349-353 (1990).

No abstract.

WP-113

UTTAL, T., J.B. SNIDER, R.A. KROPFLI, and B.W. Orr. A remote sensing method of measuring atmospheric vapor fluxes: Application to winter mountain storms. Journal of Applied Meteorology 29(1):22-34 (1990).

Vapor fluxes are calculated across a mountain barrier during two wintertime storms using a passive microwave radiometer and a Doppler radar. The vapor flux fields are shown to have complicated structures that are not detectable by conventional rawinsonde techniques. The vapor-flux fields show several major pulses which are compared to episodes of supercooled liquid water, riming, precipitation and synoptic weather patterns. It appears from this data that the presence of an enhanced vapor in the flux field is a necessary condition for precipitation, but not a sufficient condition. It is suggested that detailed measurements of the vapor flux field are imperative to the improved local forecasting of precipitation.

WP-114

Wade, C.G., and D.E. WOLFE. Performance of the Viz carbon hygristor in a dry environment. Preprints, 12th Conference on Weather Analysis and Forecasting, Monterey, CA, 2-6 October 1989. American Meteorological Society, Boston, MA, 58-62 (1989).

No abstract.

WP-115

Walsh, E.J., Waveform distortion and range error in off-nadir altimeter measurements. Proceedings, Consultative Meeting on Imaging Altimeter Requirements and Techniques, Surrey, UK, 30 May-1 June 1990. European Space Agency, Brussels, Belgium, MSSL-/RSG/900I, III.9.1-III.9.4 (1990).

This paper assumes that a radar at 800 km altitude over water employs two antennae separated by a 12-m boom to produce an interferometric pattern on the surface at 50 km cross-track. The paper examines errors in the range measurements caused by waveform distortions from effects such as wind-speed variation and absorption by rain and clouds for radar frequencies of 13.6 GHz and 35.5 GHz.

WP-116

Walsh, E.J., F.C. Jackson, D.C. Hines, C. Piazza, L.G. Hevizi, R.E. McIntosh, D.J. McLaughlin, R.N. Swift, J.F. Scott, J.K. Yungel, and E.B. Frederick. Frequency dependence of electromagnetic bias in sea surface range measurements. Proceedings, IGARSS '90, College Park, MD, 20-24 May 1990. IEEE, New York, NY, 695-698 (1990).

Range measurements made by satellite radar altimeters experience a bias toward the troughs of ocean waves. A series of aircraft flights during January to April 1989 measured this electromagnetic (EM) bias at three radar frequencies and UV under a variety of wind and wave conditions, and provided the first airborne open-ocean measurements at the K_u- and C-band operating frequencies of the TOPEX altimeter. The data suggest that (1) EM bias is fairly constant over a mesoscale region on a given day, but can fluctuate significantly from one day to another, (2) the bias varies with radar frequency, increasing as the frequency is lowered from K_u-band to C-band, (3) the bias tends to increase with wind speed but the increase is not monotonic.

WP-117

Walsh, E.J., F.C. Jackson, E.A. Uliana, and R.N. Swift. Observations on electromagnetic bias in radar altimeter sea surface measurements. Journal of Geophysical Research 94:14575-14584 (1989).

Because the relative radar cross section of the sea surface increases below mean sea level and decreases above it, the range measurements of satellite radar altimeters are biased toward the wave troughs. Published and unpublished direct measurements of this electromagnetic (EM) bias are examined as well as the predictions of theoretical developments. The EM bias is predominately a function of the radar frequency used, averaging 1.2% of the wave height of K_u band 3.3% of the wave height at X band. The airborne measurements present a consistent picture of the variation of the relative radar cross section as a function of deviation from mean sea level. A technique to measure EM bias at the K_u and C band operating frequencies of the TOPEX satellite altimeter is described.

WP-118

WEBER, B.L., and D.B. WUERTZ. Comparison of rawinsonde and wind profiler radar measurements. Journal of Atmospheric and Oceanic Technology 7(1):157-174 (1990).

Comparisons of horizontal wind component measurements from a rawinsonde and a UHF wind profiler radar, obtained twice daily over a period of nearly 2 years (from mid-January 1984 through October 1985), showed differences with a standard deviation of about 2.5 m s^{-1}, mainly due to meteorological variability in the winds.

WP-119

WESTWATER E.R., and J.B. SNIDER. Applications of ground-based radiometric observations of millimeter-wave radiation. Alta Frequenza LVIII:467-474 (1989).

The Wave Propagation Laboratory designed, constructed, and has been taking atmospheric measurements with a three-channel transportable radiometer that operates at 20.6, 31.65, and 90.0 GHz. In July 1987, the first experimental results of the system were obtained at San Nicolas Island, California, during a cloud radiation experiment. Since that time, it has been operated at Denver, Colorado, for two periods of about one month each. At Denver, it ran alongside a continuously operating six-channel radiometer that has channels at 20.6 and 31.65 GHz, and four channels in the 60-GHz emission band of molecular oxygen. Colocated radiosonde measurements were taken at least twice daily during all of the experiment. The design of the radiometer is briefly discussed, and several experimental results and applications are presented. Brightness temperature measurements are compared with the absorption models of Waters and of Liebe, oxygen absorption being calculated by a recent model of Rosenkranz. Applications are discussed, including cloud absorption measurements, attenuation statistics, climate, aircraft icing, and satellite validation.

WP-120

WESTWATER, E.R., J.B. SNIDER, M.J. FALLS, and E. Fionda. Attenuation statistics derived from emission measurements by a network of ground-based microwave radiometers. Proceedings, NAPEX XIV, Blacksburg, VA, 11-12 May 1990. NASA/JPL, Pasadena, CA, 102-109 (1990).

Two seasons (1987): December through 1988 February; and 1988: June through August) of thermal emission measurements taken by a multi-channel, ground-based microwave radiometer, are used to derive single-station zenith attenuation statistics at 20.6 and 31.65 GHz. For the summer period, statistics are also derived for 52.85 GHz. In addition, data from the two dual-channel radiometers, separated from Denver by baseline distances of 49 and 168 km, are used to derive two-station attenuation diversity statistics at 20.6 and 31.65 GHz. The multi-channel radiometer operated at Denver, Colorado; the dual-channel devices operated at Platteville and Flagler, Colorado. The diversity statistics are presented by cumulative distributions of maximum and minimum attenuation.

WP-121

WOLFE, D.E., and C.W. KING. Denver/Boulder visibility: meteorological aspects and comparisons. In Transactions: Visibility and Fine Particles, C.V. Mathai (ed.) Air and Waste Management Association, Pittsburgh, PA, 479-488 (1990).

Meteorological and nephelometer data obtained during the 1987-88 Metro Denver Brown Cloud Study and the 1988-89 Boulder Air Quality Study were used to study the temporal and spatial diversity of visible pollution along the Colorado Front Range. Results for Denver show a strong relationship between the vertical visibility distribution and the vertical temperature structure. A comparison of the visibility distribution between a rural and downtown site reveals both similarities and differences depending on the particular weather regime. A preliminary analysis of visibility data from the Boulder study suggests a relationship between visibility degradation, relative humidity, and drainage flows along Boulder Creek. Daily wind and relative humidity patterns, that directly affect visibility, are highly correlated with the dirunal heating cycle.

WP-122

WUERTZ, D.B., B.L. WEBER, R.G. STRAUCH, D.A. MERRITT, K.P. MORAN, D.C. LAW, D. VAN DE KAMP, R.B. CHADWICK, M.H. ACKLEY, M.F. BARTH, N.L. ABSHIRE, P.A. MILLER, and T.W. SCHLATTER. Evaluating the performance of the first wind profiler of the new NOAA demonstration network. Proceedings, IGARSS '90, College Park, MD, 20-24 May 1990. IEEE, New York, NY, 533-536 (1990).

No abstract.

WP-123

ZAMORA, R.J. Wind profiler observations of a pre-convective environment. Master's thesis, State University of New York, Albany, NY, 126 pp. (1989).

Recent developments in radar wind profiling techniques allow one to sample the wind field above an observing site at hourly intervals. During the month of July 1987 the National Oceanic and Atmospheric Administration (NOAA) Wave Propagation Laboratory (WPL) conducted an experiment in northeastern Colorado that utilized wind profilers and conventional meteorological observations in an attempt to diagnose atmospheric conditions prior to severe convective outbreaks. Conventional and remote-sensing measurements have been synthesized in order to examine the evolution of the pre-convective atmosphere. We found that synoptic-scale and mesoscale forcing mechanisms interacted together to prepare the atmosphere over northeastern Colorado for a severe convective outbreak on 23 July 1987.

WP-124

ZAMORA, R., and P.T. May. Wind profiler observations of mid-tropospheric cyclogenesis. Proceedings, IGARSS '90, College Park, MD, 20-24 May 1990. IEEE, New York, NY, 529-532 (1990).

No abstract.

WP-125

ZAMORA, R.J., and M.A. SHAPIRO. Wind profiler observations of a pre-convective environment. Preprints, 12th Conference on Weather Analysis and Forecasting, Monterey, CA, 2-6 October 1989. American Meteorological Society, Boston, MA, 148-155 (1989).

No abstract.

WP-126

Zhao, Y. Numerical differentiation methods for estimating ozone concentration in DIAL measurements. Proceedings, Topical Meeting onOptical Remote Sensing of the Atmosphere, Incline Village, NV, 12-15 February 1990. Optical Society of America, Washington, DC, 388-391 (1990).

No abstract.

Addendum

WP-127

Bahar, E. Generalized Fourier transforms for the acoustic pressure and velocity in compressible dissipative stratified media. Wave Motion 11:565-577 (1989).

Generalized Fourier transforms are derived for the acoustic pressure and velocity in compressible dissipative plane stratified media. The acoustic source terms are accounted for in the equations of continuity and force. The acoustic pressure and velocity are each expressed as sums of two infinite (branch cut) integrals and a discrete term. In the far field the infinite integrals correspond to the direct and specularly reflected waves and the lateral wave. The discrete term associated with the pole of the reflection coefficient is the surface wave. The transforms provide a suitable basis for the expansion of the acoustic pressure and the velocity when the height of the interface, the adiabatic bulk modulus, the equilibrium density, and the absorption of the medium vary. Both exact boundary conditons and the approximate impedance boundary condition are considered in this work.

WP-128

FAIRALL, C.W., and J.B. Edson. Modeling the droplet contribution to the sea-to-air moisture flux. In Climate and Health Implications of Bubble-Mediated Sea-Air Exchange, E.C. Monahan and M.A. Van Patten (eds.). Connecticut Sea Grant College Program, University of Connecticut, Groton, CT, 121-146 (1989).

Assessing the importance of sea spray for air-sea moisture transfer is a formidable observational and modeling problem. From a modeling perspective, the primary roadblock is the wide range of size scales (from droplet microphysical to atmospheric boundary layer) that must be considered. Both ensemble average budget equation and Monte Carlo simulation approaches are being pursued. It is now clear that the total droplet evaporation is dominated by rather large droplets (on the order of 50 μm radius) which are so massive that their turbulent transport is affected by inertia. This further complicates the modeling task. Application of ensemble average and Monte Carlo models to this problem is still in its infancy. To date, only somewhat idealized cases (fresh water, ad hoc concentration profiles, laboratory situations, etc.) have been examined. The oceanic droplet source strength as a function of wind speed also represents an important uncertainty. The current state of knowledge suggests that droplets significantly enhance the moisture transfer efficiency at wind speeds in excess of 15 ms^{-1}.

WP-129

Lopez, R.E., W.D. OTTO, J.R. Daugherty, and R.L. Holle. The relationship between radar and lightning characteristics of northeastern Colorado storm systems. Proceedings, 24th Conference on Radar Meteorology, Tallahassee, FL, 27-31 March 1989. American Meteorological Society, Boston, MA, 85-88 (1989).

No abstract.

WP-130

Rothermel, J., D. Bowdle, J.M. Vaughan, and M.J. POST. Evidence of a tropospheric aerosol backscatter background mode. Applied Optics 28(6):1040-1042 (1989).

Climatologies of aerosol backscatter profiles, derived from airborne and ground-based CO_2 lidar returns, indicate a high frequency of occurrence for a narrow range of low backscatter values within the troposphere—a background mode.

APPENDIX: FEDERAL-STATE COOPERATIVE PROGRAM IN ATMOSPHERIC MODIFICATION RESEARCH

AP-001

Anantharaj, V.G. An exploratory study of the summertime observations by a dual-wavelength microwave radiometer at Dickinson, North Dakota in 1987. M.S. Thesis, Institute of Atmospheric Sciences, South Dakota School of Mines and Technology, Rapid City, SD, 116 pp. (1990).

No Abstract.

AP-002

Boe, B.A., and J.A. Jung. The application of geostationary satellite imagery for decision-making in convective cloud seeding in North Dakota. Journal of Weather Modification, 22:73-78 (1990).

A McIDAS (Man-computer Interactive Data Access System) workstation was employed to monitor the development, movement, and eventual decay of convective clouds over target areas totalling 366,000 km^2 in western North Dakota. Information relevant to cloud seeding strategies for both rainfall enhancement and hail suppression was relayed to the field meteorologists at their radar sites in near real-time, where the operational decisions were made. Both the utility and the timeliness of the information were evaluated. Shortcomings are also discussed.

AP-003

Changnon, S.A., and S.E. Hollinger. Crop yield results from simulated rain applications to agricultural plots in Illinois. Journal of Weather Modification, 22:58-62 (1990).

Ten different levels of rainfall were applied (during 1987, 1988, and 1989) to agricultural plots in central Illinois to discern effects on corn and soybean yields. Increases in rainfall during a hot dry summer (June-August 1988) revealed sizable yield gains. For one inch of added rainfall, the yields increased 10 bu/acre for corn and 4 bu/acre for soybeans. In a summer of near average rain (1989), the increases were less, about 5 bu/acre for corn and 3 bu/acre for soybeans. When summer rainfall exceeded 14 inches, yields of both crops were decreased. The various rainfall tests revealed that rain increases done only on days when natural rainfall was $\leq$0.1 inch provided no detectable yield increases, whereas a 40% increase on all rain days (the largest increase tested) produced the greatest crop yield increase (up to the 14-inch optimum). Corn yields reacted very favorably to added rains on days with $\geq$1.0 inch of rain.

AP-004

Czys, R.R. Observed versus diagnosed ice production rates in warm-based midwestern cumuli. Proceedings, Conference on Cloud Physics, San Francisco, CA, 23-27 July 1990. American Meteorological Society, Boston, MA, 25-29 (1990).

No abstract.

AP-005

DeGrand, J.Q., A.M. Carleton, and P.J. Lamb. A mid-season climatology of jet condensation trails from high resolution satellite data. Proceedings, Conference on Atmospheric Radiation, San Francisco, CA, 23-27 July 1990. American Meteorological Society, Boston, MA, 309-311 (1990).

No abstract.

AP-006

Detwiler, A.G., P.L. Smith, and D.J. Musil. T-28 participation in the 1989 North Dakota Thunderstorm Project. Report SDSMT/IAS/-R-90/05, Institute of Atmospheric Sciences, South Dakota School of Mines and Technology, Rapid City, SD, 29 pp. + app. (1990).

No abstract.

AP-007

Finnegan, W.G., and R.L. Pitter. Ice phase induced chemical reactions. Preprints, Conference on Cloud Physics, San Francisco, CA, 23-27 July 1990. American Meteorological Society, Boston, MA, 473-474 (1990).

No abstract.

AP-008

Finnegan, W.G., and R.L. Pitter. Ice crystal breeding: A primary nucleation mechanism. Nucleation Symposium, Bethlehem, PA. American Chemical Society, June (1990).

No abstract.

AP-009

Finnegan, W.G., R.L. Pitter, and L.G. Young. Experimental study of coupled oxidation-reduction reactions of soluble ionic aerosol constituents in growing ice crystals. AAAR Annual Meeting, Sparks, NV. October (1989).

No abstract.

AP-010

Garcia, P., S.A. Changnon, and M. Pinar. Economic effects of precipitation enhancement in the corn belt. Journal of Applied Meteorology, 29:63-75 (1990).

Policy formulation in weather modification requires an understanding of the economic effects from altered weather. The focus of this study is to provide insight into the beneficiaries of a functioning weather modification technology when applied at various spatial and temporal levels. An econometric model which links the corn/soybean production to U.S. cattle, hog and poultry sectors is used to determine the effects of precipitation enhancement in the U.S. Corn Belt, a humid climatic region. A regional supply formulation permits assessment of weather modification on production, prices, revenues to producers, and savings in consumers expenditures on meat. The results provide insight into the distribution of economic effects, emphasize the importance of careful planning in the use of weather modification technology, and provide useful information on the roles of local, state, and federal governments in the support of weather modification.

AP-011

Griffith, D.A., G.W. Wilkerson, and D.A. Risch. Airborne observations of a summertime, ground-based tracer gas release. Journal of Weather Modification, 22:43-48 (1990).

Two research aircraft were equipped with real-time sulfur hexafluoride analyzers in support of the North Dakota/NOAA 1987 summertime weather modification research program. Sulfur hexafluoride (SF6) was released from a ground location and the plume was detected by both aircraft on several downwind transects. The SF6 plume was tracked to near the base of a developing thunderstorm by one of the research aircraft. Calculations were made of what the concentration of silver iodide (AgI) seeding material would have been had a seeding generator been operated concurrently with the SF6 release. These calculations utilized the SF6 release rate, and assumed AgI release rate, and the observed SF6 concentrations.

AP-012

Hirsch, J.H. North Dakota Thunderstorm Project - 1989 Field Program Data Inventory. Bulletin 89-5, Institute of Atmospheric Sciences, South Dakota School of Mines and Technology, Rapid City, SD, 133 pp. (1990).

No abstract.

AP-013

Huff, F.A. Time distributions of heavy rainstorms in Illinois. Circular 173, Available from Illinois State Water Survey, Champaign-Urbana, IL, 18 pp. (1990).

No abstract.

AP-014

Huggins, A.W. Investigations of winter mountain storms in Utah during the 1987 Utah/NOAA field program. Final report to Utah Department of Natural Resources, Division of Water Resources. Desert Research Institute, Reno, NV, 98 pp. (1990).

No abstract.

AP-015

Huggins, A.W. Investigations of winter mountain storms in Utah during the 1989 Utah/NOAA field program. Final report to Utah Department of Natural Resources, Division of Water Resources. Desert Research Institute, Reno, NV, 212 pp. (1990).

No abstract.

AP-016

Huggins, A.W., and K. Sassen. A high altitude ground-based cloud seeding experiment conducted in southern Utah. The Journal of Weather Modification, 21:1 (1990).

A wintertime ground-based cloud seeding experiment conducted as part of the 1989 Utah/NOAA cooperative weather modification program is described. The results from one experiment on 3 February 1989 are presented. Meteorological conditions led to the development of orographic clouds over the Tushar Mountains of southern Utah which appeared to be nearly ideal for seeding operations. Radiometrically measured liquid water was abundant in the vicinity of seeding generators and the water appeared to be sufficiently supercooled to enable nucleation by silver iodide. The experiment entailed pulsed releases of silver iodide from high altitude generators located on upwind ridges of the Tushar Mountains. A Ka-band radar, aspirated PMS 2D-C probe and manual microphysics observations were used to monitor precipitation 10-13 km downwind of the seeding generators. Snow samples were also collected periodically and analyzed for silver content. The overall results were disconcerting in that two estimated periods of effect showed no enhanced silver content, and no clear microphysical or radar seeding signatures due to large background variability produced by a propagating mesoscale cloud feature, and natural snow characteristics which resembled the expected characteristics due to seeding. A third period of effect had apparent microphysical and radar signatures, but also lacked the presence of silver in the snow. Targeting of the single downwind ground target apparently failed in this case due to inadequate wind documentation in the cloud layer, remote-generator malfunction, or fallout of the seeded plume upwind of the target.

AP-017

Huggins, A.W., R.J. Meitin, and R.F. REINKING. Comparison of radiometric measurements of cloud liquid water near a mountain crest and over a downwind valley. Proceedings, 5th Conference on Mountain Meteorology, Boulder, CO, 25-29 June 1990. American Meteorological Society, Boston, MA, 135-142 (1990).

No abstract.

AP-018

Knight, C.A. First radar echoes at low dBz values in convective clouds. Preprints, Conference on Cloud Physics, San Francisco, CA, 23-27 July 1990. American Meteorological Society, Boston, MA, 716-721 (1990).

No abstract.

AP-019

Kopp, F.J., J.A. Jung, and R.T. McNider. A parameterization of radiation heating at the surface in a numerical cloud model. Preprints, Conference on Cloud Physics, San Francisco, CA, 23-27 July 1990. American Meteorological Society, Boston, MA, J81-J90 (1990).

No abstract.

AP-020

Long, A.B., B.A. Campistron, and A.W. Huggins. Investigations of a winter mountain storm in Utah. Part I: Synoptic analyses, mesoscale kinematics and water release rates. Journal of the Atmospheric Sciences, 47:1302-1322 (1990).

A winter storm passing across the north-south-oriented Tushar Mountains in southwest Utah is investigated in this multipart paper. Part I describes the evolving synoptic pattern, mesoscale kinematics, and calculated water release rates (condensation or deposition) in clouds over the western upslope part of the mountains. Horizontal mesoscale kinematic variables come from direct application of Volume Velocity Processing to single C-band Doppler radar data. Water release rates are computed from updrafts derived from the radar data and from the vertical gradient of saturation mixing ratio obtained from soundings. In Stage I of the storm altostratus was present on the leading side of a

long-wave trough. Weak updrafts occurred only at the higher altitudes within the clouds where there was convergence and large-scale synoptically forced lift. Downdrafts as great as -0.6 ms^{-1} occurred in the lower parts of the cloud where there was divergence. The downdrafts were induced in part by sublimation cooling of solid (ice) precipitation falling from the altostratus. Only virga was observed and the radar echoes did not reach the surface. Stage II was initially dominated by passage of a short-wave aloft. Drier air associated with the short-wave led to complete evaporation of the altostratus of Stage I. The lower parts of the cloud (<4.5 km MSL) eventually redeveloped into altocumulus. Later in Stage II the wind veered more perpendicular to the mountains. Simultaneously, convergence developed in the lower 900-1200 m of the atmosphere, and mesoscale updrafts of 0.1-0.2 ms^{-1} were calculated. Maxima in the water release rate were associated with the updrafts. During Stage III a passing cold front influenced the kinematics and cloud and precipitation. From prior to frontal passage to a few hours afterward the wind beneath the frontal surface veered from southwesterly to northerly. There was strong convergence at low altitudes just upwind of the Tushar Mountains. It was accompanied by strong, deep mesoscale updrafts extending from near the ground up through the frontal surface and by water release maxima. The storm changed character after the wind at low altitudes had veered to northerly and had become parallel to the Tushar Mountains. Convergence maxima continued to be present beneath the frontal surface but weaker. They preceded by ~0.5 h maxima in the convergence above the frontal surface. Associated with these paired convergence features were updraft maxima located above the frontal surface. Water release rates were generally lower than earlier in Stage III. The decrease was greatest at low altitudes beneath the frontal surface where the wind veered to northerly, where there was little uplift by the Tushar Mountains, and where updrafts were weak. Above the frontal surface the decrease in water release rate was not as great inasmuch as lift by the frontal surface was still occurring. The storm dissipated in Stage IV. The axis of the longwave trough passed through the area, winds at higher altitudes beneath the frontal surface veered more northerly, and there was substantial drying at all altitudes above and below the frontal surface. The winds beneath the frontal surface were divergent, indicative of subsidence, and mesoscale downdrafts were present.

AP-021

MARTNER, B.E. Radar observations of transport and diffusion of chaff in a stratus cloud. Ninth Symposium on Turbulence and Diffusion, Roskilde, Denmark, 30 April - 3 May 1990. American Meteorological Society, Boston, MA, 115-118 (1990).

No abstract.

AP-022

MARTNER, B.E., and J.D. Marwitz. Transport and diffusion of chaff in a convective cloud. Preprints, Conference on Cloud Physics, San Francisco, CA, 23-27 July 1990. American Meteorological Society, Boston, MA, 722-729 (1990).

No abstract.

AP-023

Mitchell, D.L. Evolution of snow-size spectra predicted by the growth processes of diffusion, aggregation and riming. Preprints, Conference on Cloud Physics, San Francisco, CA, 23-27 July 1990. American Meteorological Society, Boston, MA, 270-277 (1990).

No abstract.

AP-024

Mitchell, D.L. Modeling of microphysical and radiative properties of cirrus clouds. Preprints, 7th Conference on Atmospheric Radiation, San Francisco, CA, 23-27 July 1990. J96-J101 (1990).

No abstract.

AP-025

Mitchell, D.L., R. Zhang, and R.L. Pitter. Mass-dimensional relationships for ice particles and the influence of riming on snowfall rates. Journal of Applied Meteorology, 22:63-68 (1990).

The masses, dimensions and habits of over 2800 natural ice particles precipitating from orographic winter storms in the central Sierra Nevada were obtained using photomicrographs. Ice particles that could be unambiguously classified were used to generate empirical expressions relating snow particle masses and dimensions. Many of the ice particle types had not been investigated previously. The influence of riming and aggregation on ice particle masses was examined. When possible, comparisons are made between these results and those of other experimental observations. By incorporating these mass-dimensional relationships into an expression for the ice mass content in a snowstorm, it was possible to estimate the mass fraction of the fresh snowpack resulting from accreted supercooled cloud water. The results from two storms analyzed suggest that about 30 to 40 percent of the deposited snow is composed of accreted cloud water during moderately riming snowfall.

best copy available

AP-026

Orville, H.D., F.J. Kopp, U.S. Nair, J.L. Stith, and R. Rhinehart. On the origin of ice in strong convective cells. Preprints, Conference on Cloud Physics, San Francisco, CA, 23-27 July 1990. American Meteorological Society, Boston, MA, 16-20 (1990).

No abstract.

AP-027

Orville, H.D., R.D. Farley, and F.J. Kopp. The simulation of cloud seeding effects using numerical cloud models. Annual Meeting of the American Association for the Advancement of Science, New Orleans, LA, 15-20 February 1990.

No abstract.

AP-028

Pitter, R.L., and W.G. Finnegan. The retention of ice crystal structure and habit during diffusional growth. Preprints, Conference on Cloud Physics, San Francisco, CA, 23-27 July 1990. American Meteorological Society, Boston, MA, 93-96 (1990).

No abstract.

AP-029

Pitter, R.L., and W.G. Finnegan. The effect of solute impurities on morphology of diffusion-grown ice crystals. Preprints, Conference on Cloud Physics, San Francisco, CA, 23-27 July 1990. American Meteorological Society, Boston, MA, 471-472 (1990).

No abstract.

AP-030

Pitter, R.L., and W.G. Finnegan. Ice crystal breeding. Journal of Weather Modification, 22:63-68 (1990).

When ice crystals rapidly grow and aggregate in the Desert Research Institute (DRI) cloud chamber, they frequently produce new ice crystals without the presence of ice forming nuclei. Ammonium salts, initially present in the cloud water and later detected in the ice crystals, enhanced this phenomenon. The continual ice crystal production was observed at temperatures from -4°C to -30°C, although it occurred more frequently when the ice crystals were long needles or dendrites -- highly non-spherical. Ice multiplication and secondary ice formation are commonly used in the meteorological literature to describe the phenomenon. The chemical literature (crystal growth) predates the meteorological literature and describes a similar process that occurs in systems of crystals growing in solution. The chemical literature calls the phenomenon crystal breeding. This paper describes the similarity between the systems and advances of two postulated mechanisms, both of which are consistent with our observations of ice crystal breeding and other observations of crystal breeding in solution.

AP-031

Pitter, R.L., and W.G. Finnegan. An experimental study of effects of soluble salt impurities on ice crystal processes during growth. Atmospheric Research, 25:71-88 (1990).

Experimental investigations of phenomena associated with the growth and interaction of ice crystals during free-fall in supercooled liquid water clouds are presented. This report focuses on the effects that included inorganic salts have on the microphysical processes. Dilute aqueous solutions of inorganic salts of typical concentrations and chemical composition of atmospheric cloud and precipitation water were used to form supercooled liquid water clouds in a cloud chamber. Subsequent nucleation of ice produced a cloud of rapidly growing ice crystals which simulated atmospheric ice crystal initial growth and interaction. The investigations found that the salt composition affected: (1) ice crystal morphology; (2) orientation of aggregate junctions; and (3) probability of secondary ice formation occurring during an experiment. The results were reproducible and were not as strongly affected by other experimental variabilities as by the chemical composition of the aqueous solution. A conceptual model, based upon the observed freezing potential (the Workman and Reynolds effect) which results from freezing of dilute aqueous solutions, is advanced which explains the observed phenomena.

AP-032

Priegnitz, D.L. Interactive Radar Analysis Software (IRAS). User's Guide, Version 1.0, 14 February 1990. Institute of Atmospheric Sciences, South Dakota School of Mines and Technology, Rapid City, SD, 73 pp.

No abstract.

AP-033

REINKING, R.F., J.L. Stith, and R.J. Meitin. Airborne radar and in situ studies of cloud hydrometeor, aerosol and gas transport in feeder cells and anvils. Preprints, Conference on Cloud Physics, San Francisco, CA, 23-27 July 1990. American Meteorological Society, Boston, MA 698-705 (1990).

No abstract.

AP-034

REINKING, R.F., and R.J. Meitin. Recent progress and needs in obtaining physical evidence for weather modification potentials and effects. Journal of Weather Modification, 21:85-93 (1989).

Statistical and numerical modeling approaches to assess the effects of cloud seeding require the interactive input of, and understanding derived from, measurements that provide direct evidence of natural and altered development of precipitation.
A brief review of recent progress in obtaining physical evidence to evaluate and verify potentials for and effects of precipitation enhancement and hail suppression is presented. Recent findings from the National Oceanic and Atmospheric Administration's Federal/State Cooperative Program in Weather Modification Research are emphasized, but other related results are included. In the context of many significant new advances toward proving hypotheses by direct measurement, a number of remaining needs for measurements and corresponding technologies are identified.

AP-035

Sassen, K., A.W. Huggins, A.B. Long, J.B. SNIDER, and R.J. Meitin. Investigation of a winter storm in Utah. Part II. Mesoscale structure, super-cooled liquid water development, and precipitation processes. Journal of the Atmospheric Sciences, 47:1323-1350 (1990).

A comprehensive analysis of a deep winter storm system during its passage over the Tushar Mountains of southwestern Utah is reported. The case study, drawn from the 1985 Utah/NOAA cooperative weather modification experiment, is divided into descriptions of the synoptic and kinematic properties in Part I, and storm structure and composition here in Part II. In future parts of this series, the turbulence structure and indicated cloud seeding potential will be evaluated. The analysis presented here in Part II focuses on multiple remote sensor and surface microphysical observations collected from a midbarrier (2.57 km MSL) field site. The collocated remote sensors were a dual-channel microwave radiometer, a polarization lidar, and a K-band Doppler radar. These data are supplemented by upwind, valley-based C-band Doppler radar observations, which provided a considerably larger-scale view of the storm. In general, storm properties above the barrier were either dominated by barrier-level orographic clouds or propagating mesoscale cloud systems. The orographic cloud component consisted of weakly (-3° to -10°C) supercooled liquid water (SLW) clouds in the form of an extended barrier-wide cap cloud that contained localized SLW concentrations. The spatial SLW distribution was linked to topographical features surrounding the midbarrier site, such as abrupt terrain rises and nearby ridges. This orographic cloud contributed to precipitation primarily through the riming of particles sedimenting from aloft, and also to some extent through an ice multiplication process involving graupel growth. In contrast, mesoscale precipitation bands associated with a slowly moving cold front generated much more significant amounts of snowfall. These precipitation bands periodically disrupted the shallow orographic SLW clouds. Mesoscale vertical circulations appear to have been particularly important in SLW and precipitation production along the leading edges of the bands. Since the SLW clouds during the latter part of the storm were based at the frontal boundary, SLW and precipitation gradually diminished as the barrier became submerged under the cold front. Based on a winter storm conceptual model, we conclude that low-level orographic SLW clouds, when decoupled from the overlying ice cloud layers of the storm, are generally inefficient producers of precipitation due to the typically warm temperatures at these altitudes in our region.

AP-036

Scott, R.W., and R.R. Czys. Convection intensity and seeding suitability forecasts in a dynamic seeding experiment in Illinois. 12th Conference on Weather Analysis Forecasting, Monterey, CA, 2-6 October 1989. American Meteorological Society, Boston, MA, 107-110 (1990).

No abstract.

AP-037

Scott, R.W., and R.R. Czys. An objective process to forecast convective precipitation and seedability of clouds in the midwestern United States. European Geophysical Society, XV General Assembly, Copenhagen, Denmark, 23-27 April 1990.

No abstract.

AP-038

Smith, P.L., A.G. Detwiler, J.H. Hirsch, L.R. Johnson, F.J. Kopp, J.R. Miller, Jr., H.D. Orville, and D.L. Priegnitz. Development of evaluation techniques for operational convective cloud modification projects: 1988-89 studies. Report SDSMT/IAS/R-90/01, Institute of Atmospheric Sciences, South Dakota School of Mines and Technology, Rapid City, SD, 31 pp. + app. (1990).

No abstract.

AP-039

Smith, P.L., and Z. Liu. Some statistics of sampling from exponential particle size distributions. Preprints, Conference on Cloud Physics, San Francisco, CA, 23-27 July 1990. American Meteorological Society, Boston, MA, 367-370 (1990).

No abstract.

AP-040

Stith, J.L., A.G. Detwiler, R.F. REINKING, and P.L. Smith. Investigating transport, mixing and the formation of ice in cumuli with gaseous tracer techniques. Atmospheric Research, 25:195-216 (1990).

Applications of tracer techniques using insoluble sulfur hexafluoride (SF_6) in studies of transport, mixing and the activation of silver iodide (AgI) aerosols in cumuli are presented. One cumulus was treated with SF_6 and aerosol near the cloud top (-13.5°C), in a region of little vertical transport. Up to 24% of the potential nuclei produced measurable ice particles 7 min after treatment, in accord with the results of recent laboratory measurements of activation of this aerosols by contact nucleation. A second cumulus was treated at the cloud base with SF_6 and the aerosol. The materials were transported to and mixed through the upper regions of the cloud. Ice particles evidently formed near the cloud top (estimated cloud top temperature -13°C). Only low concentrations of natural ice were found in untreated regions of the cloud. In the treated regions the ice particle concentrations in the cold, upper part of the cloud and in downdrafts at lower levels were consistent with the concentrations of AgI nuclei estimated from the tracer measurements. At lower levels of the cloud the materials were not so well mixed, the most concentrated regions being found on the upshear side of the cloud and dilute regions downshear. Mid and upper level ice concentrations were greatest in downdrafts on the downshear side, suggesting that the downdraft was important in transporting the ice to lower levels of the cloud.

AP-041

UTTAL, T., J.B. SNIDER, R.A. KROPFLI, and B.W. ORR. A remote sensing method of measuring atmospheric vapor fluxes: Application to winter mountain storms. Journal of Applied Meteorology, 29:22-34 (1990).

Vapor fluxes are calculated across a mountain barrier during two wintertime storms using a passive microwave radiometer and a Doppler radar. The vapor flux fields are shown to have complicated structures that are not detectable by conventional rawinsonde techniques. The vapor-flux fields show several major pulses which are compared to episodes of supercooled liquid water, riming, precipitation and synoptic weather patterns. It appears from this data that the presence of an enhanced vapor in the flux field is a necessary condition for precipitation, but not a sufficient condition. It is suggested that detailed measurements of the vapor flux field are imperative to the improved local forecasting of precipitation.

AP-042

Westcott, N.E. Radar results of the 1986 Exploratory Field Program relating to the design and evaluation of PACE. Journal of Weather Modification, 22:1-17 (1990).

The initial phase of the Precipitation Augmentation for Crops Experiment (PACE), directed at enhancing rainfall was conducted in Illinois during the summer of 1986. This first experiment resulted in a limited sample, (19 clouds and 3 experimental units), but one sufficient to provide information pertinent to the design and evaluation of future efforts. In particular, it was determined that differences in meteorological conditions may mask any seeding signature present, requiring that the experimental units be stratified or normalized. It was found that for these clouds, the height of the echo at first detection and the age of the echo at treatment (AgI or placebo) have an important bearing on the expected growth of the echo. Additionally, the area and reflectivity of the echo at 6 km at the time of treatment seem to be related to the maximum size attained by the echo cores. That is, the larger the echo at treatment, the larger the echo can be expected to grow. However, the growth of the echo core in terms of reflectivity, height and area appeared to slow as the echo cores matured. This suggests that explosive growth sometimes expected from cloud seeding may not be the rule in this area of the country and that a comparison of before and after treatment growth rates may not be a good evaluation tool. Rather, the post treatment growth, with the experimental units stratified by the age of the echo at treatment and by the height of formation may be more useful in discriminating seeding effects. Radar derived predictor variables were examined to assess echo behavior based on the ambient weather conditions, and response variables were developed which may be useful in detecting potential seeding effects. Inferences were made with regard to stratification of the data, experimental unit definition, and cloud behavior. This work emphasized, as others have found, the need for predictor variables and a large sample.

AP-043

Zhang, R., D.L. Mitchell, S. Chai, and R.L. Pitter. Ground-based ice particle observations for analysis of Sierra winter orographic storms. Preprints, Conference on Cloud Physics, San Francisco, CA, 23-27 July 1990. American Meteorological Society, Boston, MA, 377-378 (1990).

No abstract.

ABOUT THE AUTHOR INDEX

All authors of all publications are listed.

An asterisk indicates a first author.

ERL authors' names are typed in all capital letters.

The words "et al." indicate that a publication had more than one author.

The alphanumeric code following an author's name gives the location of the bibliographic entry. Example: WP-061 is the sixty-first entry in the Wave Propagation Laboratory section.

Following are the codes used, their meanings, and inclusive pages:

Code	Laboratory or Publishing Group	Pages
AL	Aeronomy Laboratory	1-29
AO	Atlantic Oceanographic and Meteorological Laboratory	55-68
AP	Appendix: Federal-State Cooperative Program in Atmospheric Modification Research	182-189
AR	Air Resources Laboratory	30-54
CM	Climate Monitoring and Diagnostics Laboratory	69-86
FS	Forecast Systems Laboratory	87-96
GF	Geophysical Fluid Dynamics Laboratory	97-105
GL	Great Lakes Environmental Research Laboratory	106-114
NS	National Severe Storms Laboratory	115-124
PM	Pacific Marine Environmental Laboratory	125-145
SE	Space Environment Laboratory	146-158
WP	Wave Propagation Laboratory	159-181

AUTHOR INDEX

*AAGAARD, K., et al., PM-001
*AAGAARD, K., et al., PM-002
Abdu, M.A., et al., SE-045
ABSHIRE, N.L., et al., FS-036
ABSHIRE, N.L., et al., FS-057
ABSHIRE, N.L., et al., WP-070
ABSHIRE, N.L., et al., WP-122
ACKLEY, M.H., et al., FS-057
ACKLEY, M.H., et al., WP-122
*Addis, R.P., et al., AR-001
Aimedieu, P., et al., AL-057
Akasofu, S.-I., et al., SE-037
*ALBERS, S.C., FS-001
*Albrecht, B.A., et al., WP-001
Albrecht, M.A., et al., SE-040
Albright, G., et al., WP-107
*ALBRITTON, D.L., AL-001
*ALBRITTON, D.L., et al., AL-002
*ALBRITTON, D.L., et al., AL-003
*ALBRITTON, D.L., et al., AL-004
*ALBRITTON, D.L., et al., AL-005
ALBRITTON, D.L., et al., AL-016
ALBRITTON, D.L., et al., AL-045
ALBRITTON, D.L., et al., AL-046
ALBRITTON, D.L., et al., AL-093
ALBRITTON, D.L., et al., AL-100
Alcaydc, D., et al., SE-037
*Alisbouse, J.C., et al., WP-002
*ALLEN, J., et al., SE-001
Allwine, E.J., et al., AL-094
Allwine, E., et al., AR-031
Alvos, M., et al., AR-020
*Anantharaj, V.G., AP-001
*Anderson, J.G., et al., AL-006
Anderson, J.G., et al., AL-008
Anderson, J.G., et al., AL-049
Anderson, J.G., et al., AL-052
Anderson, J.G., et al., AL-095
Anderson, J., et al., AL-098
Anderson, J., et al., SE-015
*Anderson, L.C., et al., AL-007
Anderson, L.C., et al., AL-053
*ANGELL, J.K., AR-002
*ANGELL, J.K., AR-003
*ANGELL, J.K., AR-004
*ANGELL, J.K., AR-005
*Antolik, M. A., et al., NS-001
Aoustin, Y., et al., AO-003
*Appelgate, T.B., Jr., PM-003
Arbuzova, V.N., et al., CM-045
Archuleta, J.A., et al., AR-102
Arnold, M., et al., AO-022
*ARTZ, R.S., AR-006
ARTZ, R.S., et al., AR-032
ARTZ, R.S., et al., AR-088
Arya, S.P.S., et al., AR-047
Aselmann, I., et al., AR-087
*ASH, E., et al., WP-003
*AUGUSTINE, J.A., et al., FS-002
AUGUSTINE, J.A., et al., FS-052
AUGUSTINE, J.A., et al., FS-054
*AUGUSTINE, J.A., et al., NS-002
AUGUSTINE, J.A., et al., NS-045
*Austin, J., et al., AL-008
Austin, J., et al., AL-049
Austin, J., et al., AL-068
Avery, S.K., et al., AL-034
Bachmeier, A.S., et al., AL-016
Bader, D.C., et al., AR-096
*Bahar, E., WP-004
*Bahar, E., WP-127
*Baik, J.-J., et al., AO-001
*Baik, J.-J., et al., AO-002
Bailey, M.R., et al., FS-038
Baines, P.G., et al., AR-017
Bak, F., et al., AR-081
Baker, C.G., et al., WP-042
Baker, D.N., et al., SE-014
Baker, D.N., et al., SE-043
*BAKER, E.T., PM-004
*BAKER, E.T., et al., PM-005
*BAKER, E.T., et al., PM-006
BAKER, E.T., et al., PM-023
BAKER, E.T., et al., PM-024
*Balakrishnan, N., et al., NS-003
*Balakrishnan, N., et al., NS-004
*BALDOCCHI, D.D., AR-007
*BALDOCCHI, D.D., et al., AR-008
*BALDOCCHI, D.D., et al., AR-009
BALDOCCHI, D., et al., AR-081
Baldridge, E.W., et al., AR-073
*BALSLEY, B.B., AL-009
BALSLEY, B.B., et al., AL-024
BALSLEY, B.B., et al., AL-034
BALSLEY, B.B., et al., AL-064
BALSLEY, B.B., et al., AL-092
Balson, W.E., et al., WP-072
Bandy, A., et al., PM-039
*Bane, J.M., et al., PM-007
Banjanin, Z., et al., NS-049
Banks, S., et al., CM-067
*BANTA, R., WP-005
BANTA, R.M., et al., WP-052
*BANTA, R., et al., WP-006
*BARNES, S.L., et al., FS-003
Barr, S., et al., AR-102
BARRETT, J., et al., SE-012
Barrie, L.A., et al., CM-054
Barrie, L.A., et al., CM-055
Barrie, L.A., et al., CM-068
BARTELS, D.L., et al., FS-053
*BARTELS, D.L., et al., NS-005
BARTELS, D.L., et al., NS-046
BARTELS, D., et al., NS-026
*Barth, C.A., et al., SE-002
Barth, C.A., et al., SE-042
Barth, C.A., et al., SE-049
BARTH, M.F., et al., FS-057
BARTH, M.F., et al., WP-122
BARTRAM, B.W., et al., WP-060
Basu, S., et al., CM-058
*BATES, T.S., et al., AL-010
BATES, T.S., et al., CM-032
*BATES, T.S., et al., PM-008
BATES, T.S., et al., PM-039
BATES, T.S., et al., PM-042
BATES, T.S., et al., PM-044
BATES, T.S., et al., PM-070
*Battye, W., et al., AR-098
Baugues, K.A., et al., AR-073
Baugues, K., et al., AR-098
Baum, B., et al., AL-019
Baumgardner, D., et al., AL-023
Baumgardner, D., et al., AL-036

Beck, S.M., et al., AL-016
Beck, S.M., et al., AL-045
Beck, S.M., et al., AL-093
Beck, S.M., et al., AL-100
*BEDARD, A.J., JR., WP-007
BEDARD, A.J., JR., et al., WP-010
BEDARD, A.J., JR., et al., WP-011
BEDARD, A.J., JR., et al., WP-050
BEDARD, A.J., JR., et al., WP-108
*Bedford, K.W., et al., GL-001
*Bedford, K.W., et al., GL-002
*Bedford, K.W., et al., GL-003
*BEETON, A.M., GL-004
BEETON, A.M., et al., GL-022
BEETON, A.M., et al., GL-023
BEETON, A.M., et al., GL-044
Behn, R.R., et al., PM-010
BELL, G.L., et al., GL-010
BENDER, M.A., et al., GF-017
*Bender, M.L., et al., PM-009
Bendura, R.J., et al., AL-045
Benjamin, M.M., et al., PM-063
Benjamin, S.G., et al., FS-046
*BERNARD, E.N., PM-078
*BERNARD, E.N., PM-079
*BERNARD, E.N., et al., PM-010
*BERNARD, E.N., et al., PM-011
BERNARD, E.N., et al., PM-030
BERNARD, E.N., et al., PM-058
Bhartia, P.K., et al., CM-015
Bhartia, P.K., et al., CM-024
Bierbaum, V.M., et al., AL-039
Biercamp, J., et al., PM-048
Bigelow, D.S., et al., AR-062
*BINKOWSKI, F.S., et al., AR-010
*Birkenheuer, D., FS-004
*Birkenheuer, D., et al., FS-005
Birkenheuer, D., et al., FS-023
*BITTERMAN, D.S., et al., AO-003
BLACK, M.L., et al., AO-007
BLACK, P.G., et al., AO-024
*BLACK, R.A., AO-004
*BLACK, R.A., et al., AO-005
Blanc, M., et al., SE-037
Blanchard, C.L., et al., AR-082
*BLANCHARD, D.O., NS-006
Blank, K., et al., SE-040
*Bluestein, H.B., et al., NS-007
*BOATMAN, J.F., et al., AR-011
*BOATMAN, J.F., et al., AR-012
BOATMAN, J.F., et al., AR-038
BOATMAN, J.F., et al., AR-052
BOATMAN, J.F., et al., AR-053
BOATMAN, J.F., et al., AR-088
BOATMAN, J.F., et al., AR-093
BOATMAN, J.F., et al., AR-095
BOATMAN, J.F., et al., CM-005
BOATMAN, J., et al., AR-022
BOATMAN, J., et al., AR-083
*BODHAINE, B.A., CM-003
*BODHAINE, B.A., et al., CM-004
*BODHAINE, B.A., et al., CM-005
*BODHAINE, B.A., et al., CM-006
BODHAINE, B.A., et al., CM-007
BODHAINE, B.A., et al., CM-028
BODHAINE, B.A., et al., CM-030
BODHAINE, B.A., et al., CM-031
BODHAINE, B.A., et al., CM-060
BODHAINE, B.A., et al., CM-078
*Boe, B.A., et al., AP-002
Bohlin, D., et al., SE-015
Bollinger, M.J., et al., AL-078
*Bond, N.A., et al., WP-008
Boone, P., et al., AR-075
*BORNMANN, P.L., SE-003
*BORNMANN, P.L., SE-004
*BORNMANN, P.L., SE-055
*BORNMANN, P.L., et al., SE-005
*Bouwer, S.D., et al., SE-006
Bouwman, A.F., et al., AR-087
Bowdle, D., et al., WP-130
Braathen, G., et al., AL-011
Bradley, R.S., et al., CM-079
Bradshaw, J.D., et al., AL-016
Bradshaw, J.D., et al., AL-048
Bradshaw, J.D., et al., AL-093
Bradshaw, J.D., et al., AL-100
Bradshaw, J., et al., AL-019
Bradshaw, J., et al., AL-041
Bradshaw, J., et al., AL-042
Brady, R.H., et al., FS-051
*BRANDES, E.A., NS-008
BRANDES, E., et al., NS-012
Brandt, P.N., et al., SE-044
Bravo, H.A., et al., AR-063
BRAVO, N.J., et al., AO-025
Brenner, R., et al., AR-054
Brett, M., et al., SE-040
*Breuninger, R.H., et al., AR-013
Bricher, E., et al., AO-022
*Bridgman, H.A., et al., CM-007
*Bridgman, H.A., et al., CM-008
Bridgman, H.A., et al., CM-031
Brier, G.W., et al., AO-019
*Brier, G.W., et al., AR-014
Brier, G.W., et al., AR-039
*BRIGGS, G.A., AR-015
BROCCOLI, A.J., et al., GF-021
Brock, C.A., et al., CM-056
Brothers, G.A., et al., AL-062
Brothers, G.A., et al., CM-048
*Browell, E.V., et al., AL-011
*Browell, E.V., et al., AL-012
Browell, E.V., et al., AL-055
Browell, E.V., et al., AL-056
Browell, E.V., et al., AL-062
Browell, E.V., et al., CM-048
Browell, E., et al., AL-058
*BROWN, J.M., FS-006
BROWN, J.M., et al., FS-024
BROWN, J.M., et al., FS-025
BROWN, J.M., et al., FS-053
BROWN, J., et al., NS-046
Brown, P.W., et al., NS-035
*Brown, T.J., et al., CM-001
*Brown, T.J., et al., CM-002
Brown, T.J., et al., CM-025
*Brown, T.J., et al., FS-007
Brown, T.J., et al., FS-016
*Brown, T.J., et al., SE-007
Brune, W.H., et al., AL-006
Brune, W.H., et al., AL-052
Brune, W.H., et al., AL-069
*BRYAN, K., GF-001
*BRYAN, K., GF-002
*BRYAN, K., GF-003
BRYAN, K., et al., GF-023
BRYAN, K., et al., GF-033
Buckland, A.T., et al., AL-008
Buckland, A.T., et al., AL-068
*Buhr, M.P., et al., AL-013
Buhr, M.P., et al., AL-030

Buhr, M.P., et al., AL-077
Buhr, M.P., et al., AL-078
Buhr, M., et al., AL-094
Bullas, J., et al., FS-034
*BULLOCK, O.R., Jr., AR-016
Bunker, S.S., et al., AR-001
*BURGESS, D.W., et al., NS-009
BURGESS, D.W., et al., NS-021
BURGESS, D.W., et al., NS-041
*Burkholder, J.B., et al., AL-014
Burkholder, J.B., et al., AL-067
Burlaga, L., et al., SE-015
Burnett, C.R., et al., AL-015
*Burnett, E.B., et al., AL-015
Burnside, R., et al., SE-045
*BURPEE, R.W., AO-006
*BURPEE, R.W., et al., AO-007
BURPEE, R.W., et al., AO-013
*Busalacchi, A.J., et al., PM-012
*Busalacchi, A.J., et al., PM-013
Busalacchi, A.J., et al., PM-067
Busalacchi, A.J., et al., PM-068
BUSHNELL, M., et al., AO-026
BUSHNELL, M., et al., AO-027
Busness, K., et al., AR-011
Busness, K., et al., AR-022
Butler, C.F., et al., AL-011
Butler, C.F., et al., AL-012
*BUTLER, J.H., et al., CM-009
BUTLER, J.H., et al., CM-077
*Butterfield, D.A., et al., PM-014
Byrd, G.P., et al., NS-007
Byun, D.W., et al., AR-023
*Cahalan, R.F., et al., WP-009
Caiazza, R., et al., WP-090
Call, D.L., et al., AR-056
Calvert, J.G., et al., AL-030
Campistron, B.A., et al., AP-020
Camusat, B., et al., PM-067
Camusat, B., et al., PM-068
*Canavero, F.G., et al., WP-010
*CANNON, G.A., PM-015
*CANNON, G.A., PM-016
*CANNON, G.A., et al., PM-017
*CANNON, G.A., et al., PM-018
*CAPLAN, S.J., et al., WP-011
*CARACENA, F., NS-010
*CARACENA, F., et al., FS-008
*CARACENA, F., et al., NS-011
Carbone, R.E., et al., AL-046
*CARBONE, R., et al., NS-012
*Carey, A.G., Jr., et al., AO-008
Cargill, P., et al., SE-026
Cariolle, D., et al., AL-062
Cariolle, D., et al., CM-048
Carleton, A.M., et al., AP-005
Carmack, E.C., et al., PM-001
*Carpenter, R.L., et al., NS-013
*CARRICK, H.J., et al., GL-005
*CARRICK, H.J., et al., GL-006
CARRICK, H.J., et al., GL-013
CARRICK, H.J., et al., GL-027
Carriere, K., et al., CM-058
*CARROLL, M.A., et al., AL-016
*CARROLL, M.A., et al., AL-017
*CARROLL, M.A., et al., AL-018
CARROLL, M.A., et al., AL-019
CARROLL, M.A., et al., AL-041
CARROLL, M.A., et al., AL-042
CARROLL, M.A., et al., AL-047
CARROLL, M.A., et al., AL-048
CARROLL, M.A., et al., AL-093
CARROLL, M.A., et al., AL-100
CARROLL, M.A., et al., AL-104
Carter, A.F., et al., AL-011
Carter, A.F., et al., AL-012
CARTER, D.A., et al., AL-024
CARTER, D.A., et al., AL-064
CARTER, D.A., et al., AL-092
*Castro, I.P., et al., AR-017
CAVALETTO, J.F., et al., GL-014
CAVALETTO, J.F., et al., GL-034
Cebula, R.P., et al., CM-024
CHADWICK, R.B., et al., FS-057
CHADWICK, R.B., et al., WP-122
Chai, S., et al., AP-043
*Chameides, W.L., et al., AL-019
Chan, K.R., et al., AL-023
Chan, K.R., et al., AL-025
Chan, K.R., et al., AL-026
Chan, K.R., et al., AL-027
Chan, K.R., et al., AL-028
Chan, K.R., et al., AL-029
Chan, K.R., et al., AL-036
Chan, K.R., et al., AL-037
Chan, K.R., et al., AL-053
Chan, K.R., et al., AL-055
Chan, K.R., et al., AL-058
Chan, K.R., et al., AL-068
Chan, K.R., et al., AL-069
Chan, K.R., et al., AL-085
Chan, K.R., et al., AL-086
Chan, K.R., et al., AL-095
Chan, K.R., et al., AL-097
Chan, K.R., et al., AL-098
Chan, K.R., et al., AL-099
Chan, K.R., et al., AL-106
Chan, K.R., et al., AL-118
Chan, K.R., et al., AL-119
Chan, W.H., et al., AR-062
CHANDLER, J.F., et al., GL-013
Cheng, J.S., et al., AR-010
Chang, J.S., et al., AR-024
*Chang, P., et al., GF-004
*Changnon, S.A., et al., AP-003
Changnon, S.A., et al., AP-010
Chappell, C.F., et al., FS-044
Charlson, R.J., et al., PM-070
Chen, H.Y., et al., WP-101
Chen, S., et al., NS-026
*CHERTOCK, B., WP-012
*Chin, Y.-P., et al., GL-007
CHING, J.K.S., et al., AR-094
Christie, D.R., et al., NS-019
Church, T.M., et al., AR-032
*CHURNSIDE, J.H., WP-013
*CHURNSIDE, J.H., WP-014
*CHURNSIDE, J.H., et al., WP-015
*CHURNSIDE, J.H., et al., WP-016
*CHURNSIDE, J.H., et al., WP-017
CHURNSIDE, J.H., et al., WP-034
Ciarlo, A., et al., SE-040
Cicerone, R.J., et al., AR-081
*Ciotti, P., et al., WP-018
*Clague, D.A., et al., AO-009
Clague, D.A., et al., AO-040
*CLARK, T.L., et al., AR-018
*CLARK, T.L., et al., AR-019
*CLARK, T.L., et al., AR-020
CLARK, T.L., et al., AR-023
CLARK, T.L., et al., AR-062
Clements, W.E., et al., AR-037

Clements, W.E., et al., AR-056
Clements, W.E., et al., AR-102
CLIFFORD, S.F., et al., WP-016
*CLIFFORD, S.F., et al., WP-019
CLIFFORD, S.F., et al., WP-020
CLIFFORD, S.F., et al., WP-046
CLIFFORD, S.F., et al., WP-061
CLIFFORD, S.F., et al., WP-062
Cobb, N., et al., AL-002
Coffey, M.T., et al., AL-062
Coffey, M.T., et al., AL-095
Coffey, M.T., et al., AL-119
Coffey, M.T., et al., CM-048
Cohen, N., et al., AL-112
Cohn, R.D., et al., AR-010
Cohn, R.D., et al., AR-018
*COKELET, E.D., et al., PM-019
*COLMAN, B.R., FS-009
*COLMAN, B.R., FS-010
*COLMAN, B.R., FS-011
*COLMAN, B.R., FS-012
*COLMAN, B.R., FS-013
COLMAN, B.R., et al., FS-003
Condon, E.P., et al., AL-016
Condon, E.P., et al., AL-093
Condon, E., et al., AL-019
Condon, E., et al., AL-100
Conforti, G., et al., WP-017
Conrad, R., et al., AR-081
Consortini, A., et al., WP-017
*Conway, J.W., et al., NS-014
CONWAY, T.J., et al., AR-091
*CONWAY, T.J., et al., CM-010
CONWAY, T.J., et al., CM-028
CONWAY, T.J., et al., CM-080
CONWAY, T.J., et al., CM-070
Cook, D.R., et al., AR-044
*COOK, K.H., GF-005
Cotton, W., et al., NS-012
Coulter, R.L., et al., AR-037
COVENTRY, D.H., et al., AR-019
Covert, D.C., et al., AL-010
Covert, D.C., et al., PM-008
Covert, D.S., et al., PM-070
Cowen, J.P., et al., PM-024
Cowley, S.W.H., et al., SE-036
*COX, M.D., GF-006
Craven, J.D., et al., SE-014
Craven, J.D., et al., SE-043
Crawford, G.B., et al., WP-019
*Crawford, G.B., et al., WP-020
Crawford, G.B., et al., WP-062
*CRAWFORD, T.L., et al., AR-021
CRAYNOCK, J.F., et al., AO-039
*CROLEY, T.E., II, GL-008
Crouch, C., et al., AR-083
Crowley, G., et al., SE-023
CROZER, E.A., et al., CM-040
CUMMINGS, S.R., et al., AO-020
*Cuperman, S., et al., SE-008
*Cuperman, S., et al., SE-056
CUPP, R.E., et al., WP-025
CUPP, R., et al., WP-024
CURL, H.C., JR., et al., PM-064
Currier, P.E., et al., AL-024
*Czys, R.R., AP-004
Czys, R.R., et al., AP-036
Czys, R.R., et al., AP-037
Dabberdt, W.F., et al., WP-107
Dalu, G., et al., FS-037
DAMMANN, W.P., et al., AO-039
Dasgupta, P.K., et al., AR-053
Daugherty, J.R., et al., WP-129
*Daum, P.H., et al., AR-022
DAVIES-JONES, R.P., et al., NS-007
DAVIES-JONES, R.P., et al., NS-041
*DAVIES, K., SE-009
Davis, D.D., et al., AL-016
Davis, D.D., et al., AL-019
Davis, D.D., et al., AL-041
Davis, D.D., et al., AL-042
Davis, D.D., et al., AL-048
Davis, D.D., et al., AL-093
Davis, D.D., et al., AL-100
*Davison, J., et al., PM-020
*Davison, J., et al., PM-021
de la Beaujardiere, O., et al., SE-023
de la Beaujardiere, O., et al., SE-037
de Pena, R.G., et al., AR-044
Decker, M.T., et al., WP-011
Decker, M.T., et al., WP-098
Decker, M.T., et al., WP-107
Decker, R.G., et al., WP-107
*DeGrand, J.Q., et al., AP-005
Delcroix, T., et al., PM-068
deLorenzis, B., et al., FS-034
deLorenzis, B., et al., FS-039
deLorenzis, B., et al., FS-040
*DELUISI, J.J., CM-011
*DELUISI, J.J., CM-012
DELUISI, J.J., et al., CM-005
DELUISI, J.J., et al., CM-006
*DELUISI, J.J., et al., CM-013
*DELUISI, J.J., et al., CM-014
*DELUISI, J.J., et al., CM-015
DELUISI, J.J., et al., CM-019
DELUISI, J.J., et al., CM-024
DELUISI, J.J., et al., CM-058
DELUISI, J.J., et al., CM-066
*DELWORTH, T., et al., GF-007
DELWORTH, T., et al., GF-022
*DEMARIA, M., AO-010
DEMARIA, M., et al., AO-001
DEMARIA, M., et al., AO-002
*DEMARIA, M., et al., AO-011
*DEMARIA, M., et al., AO-012
Demerjian, K.L., et al., AL-030
Denlinger, R.P., et al., AO-042
Dennis, B.R., et al., SE-031
DENNIS, R.L., et al., AR-020
*DENNIS, R.L., et al., AR-023
*DENNIS, R.L., et al., AR-024
DENNIS, R.L., et al., AR-082
*Derber, J., GF-009
*Derber, J., et al., GF-008
Derber, J., et al., NS-031
Desjardins, R.L., et al., AR-087
*Dester, G.D., et al., AL-020
*Detwiler, A.G., et al., AP-006
Detwiler, A.G., et al., AP-038
Detwiler, A.G., et al., AP-040
Detwiler, A.G., et al., WP-109
*DIAZ, H.F., CM-016
*DIAZ, H.F., CM-017
DIAZ, H.F., et al., CM-036
DIAZ, H.F., et al., CM-079
Dickerson, M.H., et al., AR-096
*Dobosy, R.J., AR-025
Dobosy, R.J., et al., AR-001
Dobosy, R.J., et al., AR-021
*Dobosy, R.J., et al., AR-026
*DODGE, P.P., et al., AO-013

DODGE, P.P., et al., AO-021
DODGE, P., et al., NS-025
DOLL, D.C., et al., AR-069
DOLL, D.C., et al., AR-073
*Domin5, F., et al., AL-021
Donahue, M.J., et al., GL-020
*DONALL, E.G., et al., WP-021
DONALL, E.G., et al., WP-081
DONALL, E.G., et al., WP-103
*DONNELLY, R.F., SE-010
*DONNELLY, R.F., SE-011
DONNELLY, R.F., et al., SE-006
*DONNELLY, R.F., et al., SE-012
DONNELLY, R.F., et al., SE-032
DONNELLY, R.F., et al., SE-051
Dorris, S., et al., AL-048
*DOSWELL, C.A., III, NS-015
*DOSWELL, C.A., III, NS-016
*DOSWELL, C.A., III, NS-017
DOSWELL, C.A., III, et al., NS-001
DOSWELL, C.A., III, et al., NS-021
*DOUGLAS, M.W., et al., NS-018
*Douglas, M.W., et al., WP-022
*Douglas, M.W., et al., WP-023
*Douglass, A.R., et al., AL-022
*DOVIAK, R.J., et al., NS-019
DOVIAK, R.J., et al., NS-022
DOVIAK, R.J., et al., NS-038
*DRAXLER, R.R., AR-027
*DRAXLER, R.R., et al., AR-028
DRAXLER, R.R., et al., AR-041
DRAXLER, R.R., et al., AR-089
Drewry, J.W., et al., AL-045
Droegemeier, K.K., et al., NS-013
Druffel, E., et al., AO-022
Drummond, J.W., et al., AL-030
DRYER, M., et al., SE-008
*DRYER, M., et al., SE-013
DRYER, M., et al., SE-034
DRYER, M., et al., SE-046
DRYER, M., et al., SE-056
du Chaffaut, A., et al., AO-003
Duce, R.A., et al., PM-039
DUNGAN, J.E., et al., GL-032
*DUNN, L.B., FS-014
*DUNN, L.B., FS-015
Durkee, P.A., et al., WP-052
*DUTTON, E.G., CM-018
DUTTON, E.G., et al., CM-006
DUTTON, E.G., et al., CM-014
*DUTTON, E.G., et al., CM-019
DUTTON, E.G., et al., CM-066
DUTTON, E.G., et al., CM-078
*Dye, J.E., et al., AL-023
Dye, J.E., et al., AL-036
Dye, J.E., et al., AL-081
EADIE, B.J., et al., GL-007
*EADIE, B.J., et al., GL-009
*EADIE, B.J., et al., GL-010
Easson, J., et al., CM-022
Eaton, B., et al., WP-003
Ebbesmeyer, C.C., et al., PM-019
Ebel, A., et al., AR-092
*EBERHARD, W.L., et al., WP-024
*EBERHARD, W.L., et al., WP-025
*EBERHARD, W.L., et al., WP-026
*EBERHARD, W.L., et al., WP-027
*EBERHARD, W.L., et al., WP-028
EBERHARD, W.L., et al., WP-040
EBERHARD, W.L., et al., WP-041
EBERHARD, W.L., et al., WP-051
EBERHARD, W.L., et al., WP-074
EBERHARD, W.L., et al., WP-112
*ECKLUND, W.L., et al., AL-024
ECKLUND, W.L., et al., AL-034
ECKLUND, W.L., et al., AL-063
ECKLUND, W.L., et al., AL-064
ECKLUND, W.L., et al., AL-074
ECKLUND, W.L., et al., AL-092
ECKLUND, W.L., et al., WP-068
ECKLUND, W.L., et al., WP-110
*ECKMAN, R.M., AR-029
ECKMAN, R.M., et al., AR-026
ECKMAN, R.M., et al., AR-060
*EDER, B.K., AR-030
*Edgington, D.N., et al., GL-011
*Edson, J.B., et al., WP-029
Edson, J.B., et al., WP-128
Egan, K.B., et al., CM-009
Egan, K.B., et al., CM-077
Ehhalt, D.H., et al., AR-081
*EILTS, M.D., et al., NS-020
Einaudi, F., et al., WP-010
*ELKINS, J.E., et al., CM-077
ELKINS, J.W., et al., CM-009
*ELKINS, J.W., et al., CM-020
ELLIOTT, W.P., et al., CM-070
ELLIOTT, W.P., et al., AR-091
Ellison, E., et al., FS-034
Ellison, E., et al., FS-039
Ellison, E., et al., FS-040
Elphic, R.C., et al., SE-014
Elphic, R.C., et al., SE-043
Elsworth, C.M., et al., AL-030
Elsworth, C.M., et al., AL-094
*EMBLEY, R.W., et al., PM-022
EMBLEY, R.W., et al., PM-041
*Erickson, D.J., III, et al., CM-021
*ESKRIDGE, R.E., et al., AR-031
ESKRIDGE, R.E., et al., AR-054
Eubank, C.S., et al., AL-028
EVANS, D.S., et al., SE-022
EVANS, D.S., et al., SE-023
EVANS, D.S., et al., SE-029
EVANS, D.S., et al., SE-037
EVANS, D.S., et al., SE-042
*Evans, M.S., et al., GL-012
*Evans, R.D., et al., CM-022
Evans, R.D., et al., CM-026
Evans, R.D., et al., CM-042
Evans, W.F., et al., CM-043
FAHEY, D.W., et al., AL-007
FAHEY, D.W., et al., AL-008
*FAHEY, D.W., et al., AL-025
*FAHEY, D.W., et al., AL-026
*FAHEY, D.W., et al., AL-027
*FAHEY, D.W., et al., AL-028
*FAHEY, D.W., et al., AL-029
FAHEY, D.W., et al., AL-030
FAHEY, D.W., et al., AL-047
FAHEY, D.W., et al., AL-049
FAHEY, D.W., et al., AL-052
FAHEY, D.W., et al., AL-053
FAHEY, D.W., et al., AL-055
FAHEY, D.W., et al., AL-057
FAHEY, D.W., et al., AL-069
FAHEY, D.W., et al., AL-078
FAHEY, D.W., et al., AL-083
FAHEY, D.W., et al., AL-086
FAHEY, D.W., et al., AL-095
FAHEY, D.W., et al., AL-118
FAHNENSTIEL, G.L., et al., GL-005

FAHNENSTIEL, G.L., et al., GL-006
*FAHNENSTIEL, G.L., et al., GL-013
FAHNENSTIEL, G.L., et al., GL-015
FAHNENSTIEL, G.L., et al., GL-045
*FAIRALL, C.W., WP-030
*FAIRALL, C.W., WP-031
FAIRALL, C.W., et al., WP-001
FAIRALL, C.W., et al., WP-029
*FAIRALL, C.W., et al., WP-032
FAIRALL, C.W., et al., WP-071
*FAIRALL, C.W., et al., WP-128
*Fairfield, D.H., et al., SE-014
Fairfield, D.H., et al., SE-043
FALLS, M.J., et al., WP-010
FALLS, M.J., et al., WP-107
FALLS, M.J., et al., WP-120
Fankhauser, J.C., et al., NS-030
Farley, R.D., et al., AP-027
Farman, J.C., et al., AL-062
Farman, J.C., et al., CM-048
Farmer, C.B., et al., AL-008
Farmer, C.B., et al., AL-049
Farmer, C.B., et al., AL-062
Farmer, C.B., et al., AL-095
Farmer, C.B., et al., CM-048
Farmer, D.F., et al., WP-019
Farmer, J.C., et al., CM-032
Farmer, J.C., et al., PM-042
Farquhar, R., et al., SE-015
FEDOR, L.S., et al., NS-018
FEDOR, L.S., et al., WP-023
FEDOR, L.S., et al., WP-103
FEDOR, L.S., et al., WP-104
FEDOR, L.S., et al., WP-105
*FEELY, R.A., et al., PM-023
*FEELY, R.A., et al., PM-024
FEELY, R.A., et al., PM-064
FEHSENFELD, F.C., et al., AL-013
*FEHSENFELD, F.C., et al., AL-030
FEHSENFELD, F.C., et al., AL-077
FEHSENFELD, F.C., et al., AL-078
FEHSENFELD, F.C., et al., AL-094
*Feldman, W., et al., SE-015
*Feldstein, S.B., et al., GF-010
Fenn, M.A., et al., AL-011
Fennell, F.F., et al., SE-014
Fergen, R., et al., AO-039
Ferguson, J.F., et al., PM-063
Fernandez, A.B., et al., AR-102
Ferraro, R.R., et al., WP-002
Ferry, G.V., et al., AL-023
Ferry, G.V., et al., AL-026
Ferry, G.V., et al., AL-028
Ferry, G.V., et al., AL-036
Ferry, G.V., et al., AL-037
Ferry, G.V., et al., AL-055
Ferry, G.V., et al., AL-118
*Fetzer, G.J., et al., WP-033
FINKELSTEIN, P.L., et al., AR-066
*Finnegan, W.G., et al., AP-007
*Finnegan, W.G., et al., AP-008
*Finnegan, W.G., et al., AP-009
Finnegan, W.G., et al., AP-028
Finnegan, W.G., et al., AP-029
Finnegan, W.G., et al., AP-030
Finnegan, W.G., et al., AP-031
*Fiocco, G., et al., CM-023
Fionda, E., et al., WP-120
Firestone, M.K., et al., AR-081
Fisher, B.D., et al., NS-034
Fisher, B.D., et al., NS-035
Fisk, M.R., et al., AO-042
*Fleig, A.J., et al., CM-024
Flueck, J.A., et al., CM-001
Flueck, J.A., et al., CM-002
*Flueck, J.A., et al., CM-025
Flueck, J.A., et al., PS-007
*Flueck, J.A., et al., PS-016
Flueck, J.A., et al., PS-050
Flueck, J.A., et al., SE-007
Flueck, J., et al., PS-034
Flueck, J., et al., PS-039
Flueck, J., et al., PS-040
FONTAINE, T.D., III, et al., GL-029
Foote, B., et al., NS-012
*FORSYTH, D.E. et al., NS-021
Foster, J.C., et al., SE-023
Foster, J.C., et al., SE-037
*FOX, C.G., PM-025
*FOX, C.G., PM-026
*FOX, C.G., PM-027
FOX, C.G., et al., PM-022
*FOX, C.G., et al., PM-028
FOX, C.G., et al., PM-038
Fozzard, R., et al., PS-035
Franchois, P.R., et al., CM-043
Franchois, P.R., et al., CM-044
Franchois, P.R., et al., CM-053
*Franchois, P., et al., CM-026
Franchois, P., et al., CM-049
Frank, L.A., et al., SE-014
Frank, L.A., et al., SE-043
Frank, L., et al., SE-001
Franke, S.J., et al., AL-020
*FRANKLIN, J.L., et al., AO-014
FRANKLIN, J.L., et al., AO-023
Frederick, E.B., et al., WP-116
Frehlich, R.G., et al., WP-015
*Frehlich, R.G., et al., WP-034
*Frehlich, R.G., et al., WP-035
FREITAG, H.P., et al., PM-053
*FREITAG, H.P., et al., PM-080
Frez, W.A., et al., GL-015
Fried, A., et al., AL-041
Friis-Christensen, E., et al., SE-023
Friis-Christensen, E., et al., SE-037
*FRISCH, A.S., et al., WP-036
*FRISCH, A.S., et al., WP-037
*FRISCH, A.S., et al., WP-038
*FRISCH, A.S., et al., WP-039
*Fritts, D.C., et al., AL-031
Fritts, D.C., et al., AL-114
Fua, D., et al., CM-023
Fukao, S., et al., AL-031
Fukao, S., et al., AL-108
Fukao, S., et al., AL-114
Fuller-Rowell, T.J., et al., SE-029
*Fulton, R., et al., NS-022
Fung, I.Y., et al., CM-069
*Fyfe, J., et al., GF-011
*GAGE, K.S., AL-032
*GAGE, K.S., AL-033
GAGE, K.S., et al., AL-024
*GAGE, K.S., et al., AL-034
*GAGE, K.S., et al., AL-035
GAGE, K.S., et al., AL-044
GAGE, K.S., et al., AL-064
GAGE, K.S., et al., AL-073
GAGE, K.S., et al., AL-074
GAGE, K.S., et al., AL-075
GAGE, K.S., et al., AL-076
GAGE, K.S., et al., AL-090

GAGE, K.S., et al., AL-091
GAGE, K.S., et al., AL-092
Gal-Chen, T., et al., AL-046
Gal-Chen, T., et al., NS-012
*Gal-Chen, T., et al., WP-040
*Gal-Chen, T., et al., WP-041
Galbally, I.E., et al., AR-081
Galchenko, V.F., et al., AR-081
Galloway, J.N., et al., AR-012
*Galloway, J.N., et al., AR-032
Galvin, A.B., et al., SE-036
Galvin, A.B., et al., SE-043
Galvin, P.J., et al., AL-030
*GAMACHE, J.F., AO-015
GAMMON, R.H., et al., CM-032
GAMMON, R.H., et al., PM-042
Gandrud, B.W., et al., AL-023
*Gandrud, B.W., et al., AL-036
*Gandrud, B.W., et al., AL-037
Gandrud, B.W., et al., AL-081
Gandrud, B.W., et al., AL-093
Gandrud, B.W., et al., AL-100
*GARCIA, H.A., SE-016
*GARCIA, H.A., SE-057
*Garcia, P., et al., AP-010
*GARDNER, W.S., et al., GL-014
*GARDNER, W.S., et al., GL-015
GARDNER, W.S., et al., GL-034
*Garratt, J.R., et al., AR-033
Garratt, J.R., et al., FS-037
Gary, B.L., et al., AL-086
Gary, B., et al., AL-036
Gary, B., et al., AL-058
Gary, B., et al., AL-098
Gary, B., et al., AL-118
*GAYNOR, J.E., et al., WP-042
GAYNOR, J.E., et al., WP-056
GEISELMAN, T.L., et al., PM-023
*GEORGES, T.M., et al., AO-016
GEORGES, T.M., et al., AO-032
GEORGES, T.M., et al., AO-033
GEORGES, T.M., et al., WP-053
GEORGES, T.M., et al., WP-054
GEORGES, T.M., et al., WP-084
GEORGES, T.M., et al., WP-085
Geotis, S., et al., NS-047
GIBSON, J.S., et al., WP-036
*Giese, B.S., et al., PM-029
Giese, B.S., et al., PM-033
GILLETTE, D.A., et al., AR-013
*GILLETTE, D.A., et al., AR-034
GILLETTE, D.A., et al., AR-035
Gloeckler, G., et al., SE-015
*GODOWITCH, J.M., AR-036
GODOWITCH, J.M., et al., AR-076
GODOWITCH, J., et al., AR-078
*GOLDAN, P.D., AL-038
GOLDAN, P.D., et al., AL-010
GOLDAN, P.D., et al., PM-008
*Golden, D.M., et al., AL-039
Goldstein, B., et al., SE-015
*Goldstein, M.K., WP-043
GONZALEZ, F.I., et al., PM-010
*GONZALEZ, F.I., et al., PM-030
GONZALEZ, F., et al., PM-081
Gopalswamy, N., et al., SE-026
*Gossard, E.E., WP-044
*Gossard, E.E., et al., WP-045
*GOTTLIEB, E.S., et al., GL-016
*GOTTLIEB, E.S., et al., GL-017
Grahek, F.E., et al., AL-094
Grahek, F., et al., AL-030
*GRASS, R.D., et al., CM-027
GRASS, R.D., et al., CM-039
GRASS, R.D., et al., CM-042
GRASS, R.D., et al., CM-044
Grassia, J., et al., PS-051
GREEN, J.L., et al., AL-075
GREEN, J.L., et al., AL-020
GREEN, J.L., et al., AL-024
GREEN, J.L., et al., AL-076
Green, J.L., et al., SE-040
*Greenblatt, G.D., et al., AL-040
Gregory, G.L., et al., AL-016
Gregory, G.L., et al., AL-017
*Gregory, G.L., et al., AL-041
*Gregory, G.L., et al., AL-042
Gregory, G.L., et al., AL-045
Gregory, G.L., et al., AL-047
Gregory, G.L., et al., AL-055
Gregory, G.L., et al., AL-062
Gregory, G.L., et al., AL-093
Gregory, G.L., et al., AL-100
Gregory, G.L., et al., CM-048
Gregory, G., et al., AL-019
*Gregory, L.G., et al., AL-043
Gregory, M., et al., NS-039
GRIFFIN, J.S., et al., AO-013
*GRIFFITH, C.G., FS-017
GRIFFITH, C.G., et al., FS-054
*Griffith, D.A., et al., AP-011
Groffman, P.M., et al., AR-081
*GROTE, U.H., FS-018
GRUBB, R.N., et al., SE-027
*Gudiksen, P.H., et al., AR-037
Gudiksen, P., et al., WP-058
GUNTER, R.L., et al., AR-011
*GUNTER, R.L., et al., AR-038
GUNTER, R.L., et al., AR-045
GUNTER, R.L., et al., AR-083
GUNTER, R.L., et al., AR-088
Gustafson, K., et al., WP-003
Haggerty, S.E., et al., AO-051
Hahn, C.H., et al., AL-078
Hahn, C.J., et al., AL-010
Hahn, C.J., et al., PM-008
Hall, B.D., et al., CM-077
Hallett, J., et al., AO-005
*Hallett, J., et al., AO-017
*HAMILTON, K., GF-012
Hammer, P.T.C., et al., PM-038
*HAMMOND, S.R., PM-031
HAMMOND, S.R., et al., PM-023
HAMPEL, T., et al., WP-105
*Han, S.M., SE-017
Hanbaba, R., et al., SE-045
*HANE, C.E., NS-023
HANE, C.E., et al., NS-013
Hansen, A.D.A., et al., CM-006
*Hansen, A.D.A., et al., CM-028
*Hansen, A.D.A., et al., CM-078
Hansen, A., et al., AR-060
*HANSEN, D.V., et al., AO-018
HANSON, K.J., et al., AR-014
*HANSON, K., et al., AO-019
*HANSON, K., et al., AR-039
*HANSON, K., et al., AR-040
Hanson, S.G., et al., WP-016
HARDER, J.W., et al., AL-062
HARDER, J.W., et al., CM-048
HARDESTY, R.M., et al., WP-025
HARDESTY, R.M., et al., WP-026

HARDESTY, R.M., et al., WP-050
HARDESTY, R.M., et al., WP-052
HARDESTY, R.M., et al., WP-088
*Hardy, K.R., et al., AL-044
Hare, J.E., et al., WP-032
Harris, G.W., et al., AL-016
Harris, G.W., et al., AL-041
HARRIS, J.M., et al., AR-088
HARRIS, J.M., et al., AR-097
*HARRIS, J.M., et al., CM-029
HARRIS, J.M., et al., CM-030
HARRIS, J.M., et al., CM-034
HARRIS, J.M., et al., CM-057
HARRIS, J.M., et al., CM-076
HARRIS, J., et al., AR-064
HARRIS, T.B., et al., CM-072
Harrison, C.G.A., et al., AO-051
*HARRISON, D.E., PM-032
HARRISON, D.E., et al., PM-020
HARRISON, D.E., et al., PM-021
HARRISON, D.E., et al., PM-029
*HARRISON, D.E., et al., PM-033
*HARRISON, D.E., et al., PM-034
*Harrison, R.A., et al., SE-018
Hart, R.L., et al., AR-044
Hartmann, D.L., et al., AL-098
*HARTMANN, H.C., et al., GL-020
HARTMANN, H.C., et al., GL-037
*HARTMANN, H.C., et al., GL-043
Harvey, J., et al., SE-015
Hasenrath, S., et al., CM-075
Hastie, D.R., et al., AL-016
Hastie, D.R., et al., AL-019
Hastie, D.R., et al., AL-041
Hastie, D.R., et al., AL-093
Hastie, D., et al., AL-048
*HAWLEY, N., et al., GL-021
HAYASHI, Y., et al., GF-030
HAYASHI, Y., et al., GF-031
Hayden, C.M., et al., AO-014
Hayden, C., et al., NS-031
*HAYES, S.P., PM-035
*HAYES, S.P., et al., PM-036
*HAYES, S.P., et al., PM-037
HAYES, S.P., et al., PM-049
HAYES, S.P., et al., PM-054
HAYES, S.P., et al., PM-055
Hayton, W.L., et al., GL-038
Healy, K.R., et al., WP-024
Healy, K.R., et al., WP-026
Hebenstreit, G.T., et al., PM-010
Heck, P., et al., WP-071
*HEFFTER, J.L., et al., AR-041
Hegg, D.A., et al., AR-053
*Heideman, K.F., FS-019
Heideman, K.F., et al., FS-056
Heideman, K., et al., FS-050
Heidt, L.E., et al., AL-008
Heidt, L.E., et al., AL-027
Heidt, L.E., et al., AL-047
Heidt, L.E., et al., AL-049
Heidt, L.E., et al., AL-055
Heidt, L.E., et al., AL-095
Heikes, B.G., et al., AL-030
Heilman, W.E., et al., AR-069
HELD, I.M., et al., GF-010
HELD, I.M., et al., GF-011
*HELD, I.M., et al., GF-013
*HELD, I.M., et al., GF-014
HELD, I.M., et al., GF-026
Hendon, H.H., et al., CM-047
Henry, M.G., et al., GL-039
Henry, R.C., et al., WP-072
HERBERT, G.A., et al., CM-006
HERBERT, G.A., et al., CM-007
HERBERT, G.A., et al., CM-008
*HERBERT, G.A., et al., CM-030
*HERBERT, G.A., et al., CM-031
HERBERT, G.A., et al., CM-034
HERBERT, G., et al., CM-019
HERMAN, A., et al., AO-018
Hevizi, L.G., et al., WP-116
Heymsfield, A.J., et al., AO-046
Heymsfield, G., et al., NS-012
*HICKS, B.B., AR-042
*HICKS, B.B., AR-043
HICKS, B.B., et al., AR-033
*HICKS, B.B., et al., AR-044
HICKS, B.B., et al., AR-059
HICKS, B.B., et al., AR-087
Higdon, N.S., et al., AL-012
*Hildebrand, J.A., et al., PM-038
*HILDNER, E., SE-019
HILDNER, E., et al., SE-018
HILDNER, E., et al., SE-026
HILL, R.J., et al., WP-017
*HILL, R.J., et al., WP-046
*HILL, R.J., et al., WP-047
*HILL, R.J., et al., WP-048
*Hillger, D.W., et al., FS-020
Hills, A.J., et al., AR-022
Hills, H.K., et al., SE-040
Hines, D.C., et al., WP-116
HIRMAN, J.W., et al., SE-024
HIRMAN, J.W., et al., SE-025
HIRMAN, J.W., et al., SE-038
*Hirsch, J.H., AP-012
Hirsch, J.H., et al., AP-038
Hjelmfelt, M., et al., NS-012
Hoard, D.E., et al., AR-056
Hobbs, P.V., et al., AR-053
Hobbs, P.V., et al., CM-056
Hoell, J.M., Jr., et al., AL-041
Hoell, J.M., Jr., et al., AL-042
*Hoell, J.M., et al., AL-045
Hofmann, D.J., et al., AL-057
Hofmann, D.J., et al., AL-062
Hofmann, D.J., et al., CM-048
HOLBROOK, J.R., et al., PM-017
*Holland, R.E., et al., GL-022
Holland, R.E., et al., GL-023
*Holland, R.E., et al., GL-044
*HOLLE, R.L., et al., NS-024
HOLLE, R.L., et al., WP-129
HOLLER, J.K., et al., WP-082
Hollinger, S.E., et al., AP-003
Holt, J.M., et al., SE-037
Holzer, T., et al., SE-015
*Hooke, W.H., et al., AL-046
*Horvath, H., et al., AR-045
HOSKER, R.P., JR., et al., AR-026
HOSKER, R.P., JR., et al., AR-037
HOSKER, R.P., JR., et al., AR-090
HOSKER, R.P., et al., AR-102
*Houde, E.D., et al., AO-020
*Houze, R.A., Jr., et al., AO-021
*Houze, R.A., et al., NS-025
Hovermale, C., et al., AL-030
HOWARD, C.J., et al., AL-014
HOWARD, C.J., et al., AL-021
HOWARD, C.J., et al., AL-039
HOWARD, C.J., et al., AL-061

HOWARD, C.J., et al., AL-067
Howard, K.J., et al., AO-042
Howell, H.B., et al., WP-107
Hoyt, S., et al., AR-063
Hsie, E.Y., et al., AL-065
Hsie, E.Y., et al., AL-078
Hu, D., et al., PM-049
*HUBER, A.H., AR-046
HUBER, A.H., et al., AR-048
HUBER, A.H., et al., AR-067
*HUBER, A.H, et al., AR-047
Hubler, G., et al., AL-016
Hubler, G., et al., AL-017
Hubler, G., et al., AL-030
*Hubler, G., et al., AL-047
Hubler, G., et al., AL-048
Hubler, G., et al., AL-078
Hubler, G., et al., AL-093
Hubler, G., et al., AL-094
Hubler, G., et al., AL-100
Hudson, H.S., et al., SE-032
*Huebert, B.J., et al., AL-048
Huebert, B.J., et al., AR-059
*Huebert, B.J., et al., PM-039
Huebert, B., et al., AL-100
*Huff, F.A., AP-013
*Huggins, A.W., AP-014
*Huggins, A.W., AP-015
*Huggins, A.W., et al., AP-016
*Huggins, A.W., et al., AP-017
Huggins, A.W., et al., AP-020
Huggins, A.W., et al., AP-035
*Huggins, A.W., et al., WP-049
Huggins, A.W., et al., WP-096
Hughes, P.M.T., et al., SE-040
Hughes, W.J., et al., SE-043
Hundhausen, A.J., et al., SE-018
Hypes, W.D., et al., AL-043
Hypes, W.D., et al., AL-055
Hypes, W., et al., AL-062
Hypes, W., et al., CM-048
Ignatowski, A., et al., FS-035
*Incze, L.S., et al., PM-040
Incze, L.S., et al., PM-071
Inoue, T., et al., AL-108
Intrieri, J.M., et al., WP-006
Intrieri, J.M., et al., WP-025
Intrieri, J.M., et al., WP-028
*Intrieri, J.M., et al., WP-050
*Intrieri, J.M., et al., WP-051
*Intrieri, J.M., et al., WP-052
Intrieri, J.M., et al., WP-112
*IRWIN, J.S., et al., AR-048
*IRWIN, J.S., et al., AR-049
Isaksen, I., et al., AL-011
Ismail, S., et al., AL-011
Ismail, S., et al., AL-012
Ismail, S., et al., AL-062
Ismail, S., et al., CM-048
Iwasaka, Y., et al., AL-057
Iwata, A., et al., AL-057
Jackson, F.C., et al., WP-063
Jackson, F.C., et al., WP-116
Jackson, F.C., et al., WP-117
*Jackson, M.E., FS-021
JACKSON, T.D., et al., PM-011
JACOBSON, M.D., et al., WP-107
JAIN, M.H., et al., NS-021
JAKOUBEK, R.O., et al., AL-062
JAKOUBEK, R.O., et al., AL-104
JAKOUBEK, R.O., et al., AL-115
JAKOUBEK, R.O., et al., CM-048
JAMISON, B.D., et al., FS-002
JAMISON, B., et al., NS-002
Jefferson, A., et al., AL-113
JOHENGEN, T.H., et al., GL-022
*JOHENGEN, T.H., et al., GL-023
JOHENGEN, T.H., et al., GL-044
*Johnson, H.P., et al., PM-041
Johnson, J.E., et al., AL-010
*Johnson, J.E., et al., CM-032
JOHNSON, J.E., et al., PM-008
*Johnson, J.E., et al., PM-042
JOHNSON, J.E., et al., PM-070
Johnson, J.W., et al., AR-009
Johnson, L.R., et al., AP-038
*Johnson, R., et al., NS-026
*Johnson, T.C., et al., AR-050
Johnston, P.V., et al., AL-057
JONES, F.J., et al., PM-028
Jones, R.L., et al., AL-008
*Jones, R.L., et al., AL-049
*Jones, R.L., et al., AL-050
*Jones, R.L., et al., AL-051
*Jones, R.L., et al., AL-052
Jones, R.L., et al., AL-055
Jones, R.L., et al., AL-068
Jones, R.L., et al., AL-069
Jones, R.L., et al., AL-081
JONES, R.M., et al., AO-032
JONES, R.M., et al., AO-033
*JONES, R.M., et al., WP-053
*JONES, R.M., et al., WP-054
JONES, R.M., et al., WP-084
JONES, R.M., et al., WP-085
JONES, R.W., et al., AO-011
Jones, V., et al., SE-015
Joranger, E., et al., CM-008
JORDAN, J.R., et al., WP-098
JORDAN, J., et al., WP-107
*JORGENSEN, D.P., et al., NS-027
JORGENSEN, D.P., et al., NS-029
JORGENSEN, D.P., et al., NS-043
Jorgensen, T., et al., AL-119
*JOSELYN, J.A., SE-020
JOSELYN, J.A., et al., CM-002
*JOSELYN, J.A., et al., SE-021
JOSELYN, J., et al., SE-007
JOSELYN, J., et al., SE-045
*Joseph, P.V., CM-033
Jun, L., et al., AR-054
Jung, J.A., et al., AP-002
Jung, J.A., et al., AP-019
Kahl, J.D., et al., CM-008
Kahl, J.D., et al., CM-029
*Kahl, J.D., et al., CM-034
Kahl, J.D., et al., CM-054
Kahl, J.D., et al., CM-055
*KAIMAL, J.C., WP-055
KAIMAL, J.C., et al., WP-037
KAIMAL, J.C., et al., WP-042
*KAIMAL, J.C., et al., WP-056
*KAIMAL, J.C., et al., WP-057
Kamei, T., et al., SE-040
Kamide, Y., et al., SE-037
KAPLAN, J., et al., AO-014
Karecki, D.R., et al., AL-016
Karecki, D.R., et al., AL-041
Karecki, D.R., et al., AL-093
*Karl, T.R., et al., CM-079
*Karoly, D.J., GF-016
*Karoly, D.J., et al., GF-015

Kato, S., et al., AL-031
Kato, S., et al., AL-108
Kato, S., et al., AL-114
Kawa, S.R., et al., AL-025
Kawa, S.R., et al., AL-027
KAWA, S.R., et al., AL-029
*Kawa, S.R., et al., AL-053
Keene, W.C., et al., AR-032
Keene, W.D., et al., AR-012
*KEILTY, T.J., GL-024
*KEILTY, T.J., et al., GL-025
Kellogg, P., et al., SE-015
KELLY, K.K., et al., AL-017
KELLY, K.K., et al., AL-023
KELLY, K.K., et al., AL-026
KELLY, K.K., et al., AL-027
KELLY, K.K., et al., AL-028
KELLY, K.K., et al., AL-037
KELLY, K.K., et al., AL-043
KELLY, K.K., et al., AL-047
KELLY, K.K., et al., AL-049
*KELLY, K.K., et al., AL-054
*KELLY, K.K., et al., AL-055
KELLY, K.K., et al., AL-069
KELLY, K.K., et al., AL-071
KELLY, K.K., et al., AL-083
KELLY, K.K., et al., AL-084
KELLY, K.K., et al., AL-085
KELLY, K.K., et al., AL-086
KELLY, K.K., et al., AL-096
KELLY, K.K., et al., AL-099
KELLY, K.K., et al., AL-106
KELLY, K.K., et al., AL-118
KELLY, K., et al., AL-036
KELLY, K., et al., AL-095
*Kelsch, M., et al., FS-022
Kempf, J., et al., GL-003
Kendall, A.W., Jr., et al., PM-075
Kerr, C.L., et al., GF-017
*Kessler, W.S., PM-043
Keyser, D., et al., WP-106
*Khalsa, S.J.S., CM-035
Khalsa, S.J.S., et al., CM-073
Khattatov, V.U., et al., CM-045
*Khurshudyan, L.H., et al., AR-051
*Kiene, R.P., et al., PM-044
Kihl, R., et al., AR-013
*Kikuchi, T., et al., SE-022
Kikuchi, T., et al., SE-045
*Kiladis, G.N., et al., CM-036
*Kiladis, G.N., et al., CM-037
Kim, D., et al., FS-005
*Kim, D., et al., FS-023
*Kim, Y.J., et al., AR-052
KING, C.W., et al., AR-102
*KING, C.W., et al., WP-058
*KING, C.W., et al., WP-059
KING, C.W., et al., WP-074
KING, C.W., et al., WP-075
KING, C.W., et al., WP-121
Kiplinger, A.L., et al., SE-031
Kiplinger, A., et al., SE-040
Kirk, E., et al., PM-048
Kittel, T.G.F., et al., FS-037
Kjome, N.T., et al., CM-059
Kleinman, L.I., et al., AR-022
KLEMM, C., et al., GL-039
Kley, D., et al., AL-066
Klitgord, K.D., et al., AO-042
Knap, A.H., et al., AR-032
*Knight, C.A., AP-018
*Knipp, D.J., et al., SE-023
Knuteson, R.O., et al., WP-107
Ko, M.K.W., et al., AL-028
*Ko, M.K.W., et al., AL-056
Ko, M.K.W., et al., AL-095
KOENIG, G.L., et al., CM-014
KOENIG, G.L., et al., CM-022
KOENIG, G., et al., CM-026
Kok, G.L., et al., AL-030
*Kok, G.L., et al., AR-053
KOMHYR, W.D., et al., CM-022
KOMHYR, W.D., et al., CM-023
KOMHYR, W.D., et al., CM-026
KOMHYR, W.D., et al., CM-027
*KOMHYR, W.D., et al., CM-038
*KOMHYR, W.D., et al., CM-039
*KOMHYR, W.D., et al., CM-040
*KOMHYR, W.D., et al., CM-041
*KOMHYR, W.D., et al., CM-042
*KOMHYR, W.D., et al., CM-043
*KOMHYR, W.D., et al., CM-044
*KOMHYR, W.D., et al., CM-045
KOMHYR, W.D., et al., CM-049
KOMHYR, W.D., et al., CM-050
KOMHYR, W.D., et al., CM-052
KOMHYR, W.D., et al., CM-053
KOMHYR, W.D., et al., CM-055
KOMHYR, W.D., et al., CM-072
KOMHYR, W., et al., AL-062
KOMHYR, W., et al., CM-048
*Kondo, Y., et al., AL-057
Kooi, S.A., et al., AL-011
Kooi, S., et al., AL-062
Kooi, S., et al., CM-048
Kopcewicz, B., et al., AR-064
Kopcewicz, B., et al., AR-080
*Kopp, F.J., et al., AP-019
Kopp, F.J., et al., AP-026
Kopp, F.J., et al., AP-027
Kopp, F.J., et al., AP-038
Kreitzberg, C.W., et al., AL-046
Kreitzberg, C.W., et al., WP-081
Krimigis, S.M., et al., SE-015
Kristensen, L., et al., WP-057
Kroeger, K.S., et al., AL-060
Krogslund, K.A., et al., PM-024
Kroll, J.T., et al., AO-012
KROPFLI, R.A., et al., AP-041
*KROPFLI, R.A., et al., WP-060
KROPFLI, R.A., et al., WP-065
KROPFLI, R.A., et al., WP-086
KROPFLI, R.A., et al., WP-090
KROPFLI, R.A., et al., WP-091
KROPFLI, R.A., et al., WP-112
KROPFLI, R.A., et al., WP-113
Krueger, A.J., et al., AL-043
Krueger, A.J., et al., AL-062
Krueger, A.J., et al., AL-086
Krueger, A.J., et al., CM-048
Krueger, A., et al., AL-056
Krumpe, P., et al., PM-010
Kuan, C., et al., GL-003
*KUNCHES, J.M., et al., SE-024
*KUNCHES, J.M., et al., SE-025
Kundu, M., et al., SE-015
*Kundu, M., et al., SE-026
*KURIHARA, Y., et al., GF-017
KUSTER, W.C., et al., AL-010
KUSTER, W.C., et al., PM-008
*LAIRD PERNIE, G., et al., GL-027
*LAIRD, G.A., et al., GL-026

Lait, L.R., et al., AL-096
Lait, L.R., et al., AL-097
Lait, L.R., et al., AL-098
Lait, L.R., et al., AL-099
Lait, L.R., et al., AL-119
*Lait, R.L., et al., AL-058
*Lalou, C., et al., AO-022
Lamb, B.K., et al., AR-068
Lamb, B., et al., AR-031
*Lamb, B., et al., AR-054
LAMB, M.F., et al., PM-024
Lamb, P.J., et al., AP-005
Lampru, P.D., et al., FS-034
Lampru, P.D., et al., FS-039
Lampru, P.D., et al., FS-040
Lander, J.F., et al., PM-010
LANDRUM, P.F., et al., GL-009
LANDRUM, P.F., et al., GL-012
LANDRUM, P.F., et al., GL-014
LANDRUM, P.F., et al., GL-025
*LANDRUM, P.F., et al., GL-028
LANDRUM, P.F., et al., GL-039
Landsea, C., et al., AO-050
*Landsteiner, M.C., et al., PM-045
*LANG, G.A., et al., GL-029
*Lang, P.M., et al., CM-046
Lang, P.M., et al., CM-080
Lang, S.L., et al., NS-040
Lange, R., et al., AR-001
Langford, A.O., et al., AL-030
Langstaff, J., et al., AR-098
*LARSEN, J.C., PM-046
*LARSEN, J.C., PM-047
LARSEN, J.C., et al., AL-062
LARSEN, J.C., et al., CM-048
LARSEN, J., et al., CM-032
LARSEN, J., et al., PM-042
Larsen, S.E., et al., WP-029
Larsen, S., et al., PM-039
LATAITIS, R.J., et al., WP-019
LATAITIS, R.J., et al., WP-020
LATAITIS, R.J., et al., WP-046
LATAITIS, R.J., et al., WP-047
*LATAITIS, R.J., et al., WP-061
*LATAITIS, R.J., et al., WP-062
LATHROP, J. A., et al., CM-045
LATHROP, J.A., et al., CM-040
LATHROP, J.A., et al., CM-041
*Latif, M., et al., PM-048
LAU, N.C., et al., GF-029
Lau, T.-K., et al., PM-028
Laulainen, N., et al., AR-011
Lauritsen, D.K., et al., NS-041
LAVELLE, J.W., et al., PM-066
LAW, D.C., et al., FS-036
LAW, D.C., et al., FS-057
LAW, D.C., et al., WP-070
LAW, D.C., et al., WP-122
Lawrence, M.B., et al., AO-012
*LAWSON, R.E., Jr., AR-055
LAWSON, R.E., Jr., et al., AR-051
LAWSON, R.E., Jr., et al., AR-056
Lazarus, A., et al., SE-015
Lazrus, A.L., et al., AR-022
LeBel, P.J., et al., AL-048
LeBel, P.J., et al., AL-100
*Lee, J.T., et al., AR-056
*Lee, J.T., et al., NS-028
Lee, R., et al., AR-011
Lee, T.J., et al., FS-037
Leitinger, R., et al., SE-045
Lemon, L.R., et al., NS-009
*LeMone, M.A., et al., NS-029
*LeMone, M.A., et al., NS-030
LeMone, M.A., et al., NS-032
Leonard, R.K., et al., CM-039
Leonard, R.K, et al., CM-042
Leonard, R.K, et al., CM-044
Leone, J.M., Jr., et al., AR-096
*LESHKEVICH, G.A., GL-030
Leslie, A.C.D., et al., AR-022
Lester, M., et al., SE-045
*LEVITUS, S., GF-018
*LEVITUS, S., GF-019
*LEWIS, J., et al., NS-031
*LEWIS, L.D., et al., SE-027
Li, S.M., et al., CM-054
LIEBIG, J.R., et al., GL-041
*Liebmann, B., et al., CM-047
Lilley, M.D., et al., PM-014
Lilly, D.K., et al., NS-036
Lindberg, S.E., et al., AR-044
Lindgren, P.F., et al., AR-053
*LINDNER, S.R., GL-031
*LIPPS, F., GF-020
Little, C.G., et al., AL-046
Little, C.G., et al., WP-052
*Liu, A.K., et al., WP-063
*Liu, C.-M., et al., AL-059
Liu, C.H., et al., AL-020
LIU, S.C., et al., AL-059
LIU, S.C., et al., AL-065
LIU, S.C., et al., AL-078
Liu, Z., et al., AP-039
Loewenstein, M., et al., AL-011
Loewenstein, M., et al., AL-022
Loewenstein, M., et al., AL-023
Loewenstein, M., et al., AL-026
Loewenstein, M., et al., AL-027
Loewenstein, M., et al., AL-028
Loewenstein, M., et al., AL-029
Loewenstein, M., et al., AL-036
Loewenstein, M., et al., AL-053
Loewenstein, M., et al., AL-055
Loewenstein, M., et al., AL-058
Loewenstein, M., et al., AL-069
Loewenstein, M., et al., AL-085
Loewenstein, M., et al., AL-086
Loewenstein, M., et al., AL-097
Loewenstein, M., et al., AL-098
Loewenstein, M., et al., AL-099
Loewenstein, M., et al., AL-106
Loewenstein, M., et al., AL-118
Loewenstein, M., et al., AL-119
London, J., et al., AL-079
London, J., et al., AL-080
*London, J., et al., SE-028
London, J., et al., SE-032
*Long, A.B., et al., AP-020
Long, A.B., et al., AP-035
Long, A.B., et al., WP-096
Longenecker, D.U., et al., CM-013
Longenecker, D.U., et al., CM-014
Longenecker, D.U., et al., CM-015
LOPEZ, R.E., et al., NS-024
*LOPEZ, R.E., et al., WP-129
Lorca, E., et al., PM-010
*Lord, S.J., et al., AO-023
*Lovejoy, E.R., et al., AL-060
*Lovejoy, E.R., et al., AL-061
Lovejoy, E.R., et al., AL-072
Lowenthal, D.H., et al., CM-057

Lu, C., et al., NS-042
Lu, I.T., et al., WP-101
Lu, N.P., et al., AR-064
Lubbers, L., III, et al., AO-020
Lubker, S.J., et al., CM-081
Ludlow, L., et al., GL-037
Luecken, D., et al., AR-011
Lupton, J.E., et al., PM-005
Lupton, J.E., et al., PM-014
Luria, M., et al., AR-093
Luria, M., et al., AR-095
Lusis, M.A., et al., AR-062
Lusk, C., et al., FS-034
Lusk, C., et al., FS-039
Lusk, C., et al., FS-040
Luther, D.S., et al., PM-034
Lynch, M.J., et al., WP-107
Lyons, J.H., et al., CM-056
MacGORMAN, D.R., et al., NS-042
*MACHTA, L., AR-057
MacKay, G.I., et al., AL-016
Mackay, G.I., et al., AL-030
MacKay, G.I., et al., AL-041
MacKay, G.I., et al., AL-093
MADDOX, R.A., et al., NS-005
MADDOX, R.A., et al., NS-041
Madronich, S., et al., AL-016
Madronich, S., et al., AL-019
Madronich, S., et al., AL-094
*Maeda, S., et al., SE-029
MAHLMAN, J.D., et al., AL-002
Malm, W.C., et al., AR-070
MANABE, S., et al., GF-007
*MANABE, S., et al., GF-021
*MANABE, S., et al., GF-022
*MANABE, S., et al., GF-023
MANABE, S., et al., GF-033
*MANGUM, L.J., et al., PM-049
MANGUM, L.J., et al., PM-055
Manka, R.H., et al., SE-043
Mankin, W.G., et al., AL-095
Mankin, W.G., et al., AL-119
Mankin, W., et al., AL-062
Mankin, W., et al., CM-048
Marche, P., et al., CM-022
Margitan, J.J., et al., AL-022
Margitan, J.J., et al., AL-058
*Margitan, J.J., et al., AL-062
Margitan, J.J., et al., AL-085
Margitan, J.J., et al., AL-086
*Margitan, J.J., et al., CM-048
MARKS, F.D., JR., et al., AO-013
*MARKS, F.D., JR., et al., AO-024
Marroquin, A., et al., FS-008
*Marroquin, A., et al., FS-024
*Marroquin, A., et al., FS-025
MARROQUIN, A., et al., NS-011
Marshall, R., et al., GL-003
Marshall, T.C., et al., NS-041
Martin, R.C., et al., CM-046
Martin, R.F., Jr., et al., SE-039
Martin, R.L., et al., AL-098
*MARTNER, B.E., AP-021
*MARTNER, B.E., WP-064
*MARTNER, B.E., et al., AP-022
MARTNER, B.E., et al., WP-036
MARTNER, B.E., et al., WP-037
*MARTNER, B.E., et al., WP-065
*MARTNER, B.E., et al., WP-066
MARTNER, B.E., et al., WP-090
MARTNER, B.E., et al., WP-091
Marwitz, J.D., et al., AP-022
Marwitz, J.D., et al., WP-066
Masarie, K.A., et al., CM-046
MASSOTH, G.J., et al., PM-006
MASSOTH, G.J., et al., PM-014
MASSOTH, G.J., et al., PM-023
MASSOTH, G.J., et al., PM-024
Masters, J., et al., AO-050
Mateer, C.L., et al., CM-013
Mateer, C.L., et al., CM-015
MATEJKA, T., et al., NS-030
*MATEJKA, T., et al., NS-032
*MATEJKA, T., et al., NS-033
Matheson, L.D., et al., SE-005
Matrosov, S.Y., et al., WP-060
Matson, P.A., et al., AR-087
MATT, D.R., et al., AR-044
Matthews, W.A., et al., AL-057
Matthews, W.A., et al., CM-043
*Matthews, W.A., et al., CM-049
Matthews, W.A., et al., CM-053
Mauch, L., et al., AR-070
MAUL, G.A., et al., AO-019
*MAUL, G.A., et al., AO-025
*MAUL, G.A., et al., AO-026
*MAUL, G.A., et al., AO-027
MAUL, G.A., et al., AR-039
Mauldin, R.L., III, et al., AL-107
*MAY, P.T., et al., AL-063
May, P.T., et al., WP-061
*May, P.T., et al., WP-067
*May, P.T., et al., WP-068
*May, P.T., et al., WP-069
May, P.T., et al., WP-079
May, P.T., et al., WP-099
May, P.T., et al., WP-107
May, P.T., et al., WP-110
May, P.T., et al., WP-111
May, P.T., et al., WP-124
MAYER, D.A., et al., AO-026
*MAYER, D.A., et al., AO-028
*MAZUR, V., et al., NS-034
*MAZUR, V., et al., NS-035
MAZUR, V., et al., NS-047
*MCAFEE, J.R., et al., AL-064
MCAFEE, J.R., et al., AL-090
MCAFEE, J.R., et al., AL-091
McBeth, R., et al., WP-107
McCaul, E.W., Jr., et al., NS-007
McClain, J.S., et al., AO-042
McCormick, M.P., et al., AL-055
McCormick, M.P., et al., AL-056
McCormick, M.P., et al., AL-058
McCormick, M.P., et al., AL-062
McCormick, M.P., et al., AL-082
McCormick, M.P., et al., AL-095
McCormick, M.P., et al., CM-048
*MCCOY, M.C., FS-026
*MCCOY, M.C., et al., FS-027
McCrea, I.W., et al., SE-023
McDuff, R.E., et al., PM-006
McDuff, R.E., et al., PM-014
McElroy, M.B., et al., AL-097
McElroy, M.B., et al., AL-119
*MCGINLEY, J.A., FS-028
*MCGINLEY, J.A., FS-029
*MCGINLEY, J.A., FS-030
MCGINLEY, J.A., et al., FS-045
MCGINLEY, J.A., et al., FS-048
MCGINLEY, J.A., et al., FS-049
McGown, M.R., et al., AR-070

McGuire, R.E., et al., SE-040
McHenry, J.N., et al., AR-010
McHenry, J.N., et al., AR-023
McHenry, J.N., et al., AR-024
*McINTOSH, P.S., SE-030
McINTOSH, P.S., et al., SE-035
McINTOSH, P.S., et al., SE-052
McIntosh, P., et al., FS-059
McIntosh, R.E., et al., WP-116
*McKeen, S.A., et al., AL-065
*McKeen, S., et al., AL-066
*McKellar, A.R.W., et al., AL-067
McKenna, D.S., et al., AL-008
McKenna, D.S., et al., AL-049
McKenna, D.S., et al., AL-050
McKenna, D.S., et al., AL-051
McKenna, D.S., et al., AL-052
McKenna, D.S., et al., AL-055
*McKenna, D.S., et al., AL-068
*McKenna, D.S., et al., AL-069
McKenna, D.S., et al., AL-081
McLaughlin, C.J., et al., WP-116
MCLAUGHLIN, R.J., et al., AL-087
McLeod, J.C., et al., FS-034
McLeod, J.C., et al., FS-039
McLeod, J.C., et al., FS-040
McManamon, P.M., et al., PM-010
*MCMILLEN, R.T., AR-058
MCMILLEN, R.T., et al., AR-021
MCMILLEN, R.T., et al., AR-044
McMillin, L.M., et al., WP-099
McMurray, G.R., et al., AO-042
McNeal, R.J., et al., AL-045
McNice, G.T., et al., WP-027
McNice, G.T., et al., WP-089
McNider, R.T., et al., AP-019
McPeters, R.D., et al., CM-038
*McPeters, R.D., et al., CM-050
*MCPHADEN, M.J., PM-050
*MCPHADEN, M.J., PM-051
*MCPHADEN, M.J., PM-052
MCPHADEN, M.J., et al., PM-009
MCPHADEN, M.J., et al., PM-012
MCPHADEN, M.J., et al., PM-013
MCPHADEN, M.J., et al., PM-036
MCPHADEN, M.J., et al., PM-037
MCPHADEN, M.J., et al., PM-045
MCPHADEN, M.J., et al., PM-048
*MCPHADEN, M.J., et al., PM-053
*MCPHADEN, M.J., et al., PM-054
*MCPHADEN, M.J., et al., PM-055
*MCPHADEN, M.J., et al., PM-056
*MCPHADEN, M.J., et al., PM-057
MCPHADEN, M.J., et al., PM-067
MCPHADEN, M.J., et al., PM-068
MCPHADEN, M.J., et al., PM-080
MEIS, P.J., et al., PM-038
Meitin, R.J., et al., AP-017
Meitin, R.J., et al., AP-033
Meitin, R.J., et al., AP-034
Meitin, R.J., et al., AP-035
Meitin, R.J., et al., WP-049
Meitin, R.J., et al., WP-092
Meitin, R.J., et al., WP-093
Meitin, R., et al., WP-096
Mellott, M., et al., SE-015
Meneghini, R., et al., NS-027
*MERREM, F.H., FS-031
MERREM, F.H., et al., FS-051
Merrill, J.T., et al., AR-088
MERRITT, D.A., et al., FS-057
MERRITT, D.A., et al., WP-038
MERRITT, D.A., et al., WP-039
MERRITT, D.A., et al., WP-069
MERRITT, D.A., et al., WP-110
MERRITT, D.A., et al., WP-111
MERRITT, D.A., et al., WP-122
Merry, C.J., et al., GL-001
Mestayer, P.G., et al., WP-029
Meyer, E.L., Jr., et al., AR-098
MEYERS, T.P., et al., AR-008
*MEYERS, T.P., et al., AR-059
MEYERS, T.P., et al., AR-101
Mielke, P.W., Jr., et al., FS-027
*Mikkelsen, T., et al., AR-060
MILBURN, H.B., et al., PM-010
MILBURN, H.B., et al., PM-011
MILBURN, H.B., et al., PM-056
*MILBURN, H.B., et al., PM-058
MILBURN, H.B., et al., PM-061
MILLER, A.J., et al., AL-002
MILLER, G.S., et al., GL-016
MILLER, G.S., et al., GL-017
*MILLER, G.S., et al., GL-032
Miller, H.L., Jr., et al., AL-103
*MILLER, J.M., AR-061
MILLER, J.M., et al., AR-032
Miller, J.R., Jr., et al., AP-038
MILLER, J., et al., AR-100
*MILLER, K.L., et al., AO-029
MILLER, P.A., et al., FS-057
MILLER, P.A., et al., WP-122
MILLS, O.A.., et al., AL-087
*Minnis, P., et al., WP-071
Minschwaner, K.R., et al., AL-015
Misra, P.K., et al., AR-062
Mitchell, D.G., et al., SE-043
*Mitchell, D.L., AP-023
*Mitchell, D.L., AP-024
*Mitchell, D.L., et al., AP-025
Mitchell, D.L., et al., AP-043
Mitchell, J.L., et al., AO-027
Mitchell, J., et al., AR-054
*MIYAKODA, K., et al., GF-024
MIYAKODA, K., et al., GF-032
*Mobley, C.D., PM-059
*MOFJELD, H.O., PM-060
Mohnen, V.A., et al., AL-030
Molenar, J.V., et al., AR-070
MOLINARI, R.L., et al., AO-028
Moll, R.A., et al., GL-040
Moncrief, M., et al., NS-012
*MONINGER, W.R., FS-032
*MONINGER, W.R., FS-033
*MONINGER, W.R., et al., FS-034
*MONINGER, W.R., et al., FS-035
MONINGER, W.R., et al., FS-039
MONINGER, W.R., et al., FS-040
MONINGER, W.R., et al., FS-050
MONINGER, W.R., et al., FS-051
*MONINGER, W.R., et al., FS-059
Montzka, D.D., et al., AL-016
Montzka, D.D., et al., AL-017
MONTZKA, D.D., et al., AL-047
Mooney, L.E., et al., NS-021
MORAN, K.P., et al., AL-063
*MORAN, K.P., et al., FS-036
MORAN, K.P., et al., FS-057
MORAN, K.P., et al., WP-067
MORAN, K.P., et al., WP-068
MORAN, K.P., et al., WP-069
*MORAN, K.P., et al., WP-070

MORAN, K.P., et al., WP-107
MORAN, K.P., et al., WP-110
MORAN, K.P., et al., WP-111
MORAN, K.P., et al., WP-122
MOREHEAD, N.R., et al., GL-009
MOUNT, G.H., et al., AL-062
MOUNT, G.H., et al., AL-104
MOUNT, G.H., et al., AL-115
MOUNT, G.H., et al., CM-048
*MOXIM, W.J., GF-025
Mudroch, A., et al., GL-036
*Mueller, P.K., et al., WP-072
Muench, R.D., et al., PM-077
Murcray, D.G., et al., AL-057
*MURPHY, D.M., AL-070
MURPHY, D.M., et al., AL-026
MURPHY, D.M., et al., AL-028
MURPHY, D.M., et al., AL-049
MURPHY, D.M., et al., AL-055
*MURPHY, D.M., et al., AL-071
MURPHY, K.M., et al., PM-022
Murphy, P.C., et al., AL-030
Murphy, P.C., et al., AL-078
Murrells, T.P., et al., AL-021
Murrells, T.P., et al., AL-061
*Murrells, T.P., et al., AL-072
Musil, D.J., et al., AP-006
MUZZI, R.W., et al., GL-032
NAGAMOTO, C.T., et al., AR-065
NAGAMOTO, C., et al., AR-063
NAGAMOTO, C., et al., AR-064
Nair, U.S., et al., AP-026
NAKAMURA, A.I., et al., PM-056
*NAKAMURA, A.I., et al., PM-061
*Nakamura, N., et al., GF-026
*NALEPA, T.F., GL-033
*Napolitano, D.J., et al., PM-081
*NAPPO, C.J., AR-099
Nastrom, G.D., et al., AL-035
*Nastrom, G.D., et al., AL-073
*Nastrom, G.D., et al., AL-074
*Nastrom, G.D., et al., AL-075
*Nastrom, G.D., et al., AL-076
NATH, M.J., et al., GF-029
*NEFF, W.D., WP-073
NEFF, W.D., et al., AR-037
NEFF, W.D., et al., AR-102
NEFF, W.D., et al., WP-072
*NEFF, W.D., et al., WP-074
*NEFF, W.D., et al., WP-075
*NEFF, W.D., et al., WP-076
*NEFF, W.D., et al., WP-077
*NEFF, W.D., et al., WP-078
NEIMAN, P.J., et al., WP-021
*NEIMAN, P.J., et al., WP-079
*NEIMAN, P.J., et al., WP-080
*NEIMAN, P.J., et al., WP-081
NEIMAN, P.J., et al., WP-103
Nekrasov, I.V., et al., AR-051
NELSON, D.W., et al., CM-072
Nesbitt, L., et al., WP-053
Nesbitt, L., et al., WP-054
Newman, P.A., et al., AL-058
Newman, P.A., et al., AL-096
Newman, P.A., et al., AL-097
Newman, P.A., et al., AL-098
Newman, P.A., et al., AL-099
Newman, P.A., et al., AL-119
NEWMAN, R., et al., PM-061
Niiler, P.P., et al., AO-003
*Nitta, N., et al., SE-031
NORTON, R.B., et al., AL-013
NORTON, R.B., et al., AL-030
NORTON, R.B., et al., AL-077
NORTON, R.B., et al., AL-094
Novakov, T., et al., CM-028
O'Hara, D., et al., AL-100
Ochs, G.R., et al., WP-035
Ochs, G.R., et al., WP-048
*Ochs, G.R., et al., WP-082
Ofman, L., et al., SE-008
Ofman, L., et al., SE-056
OGrady, K., et al., GL-037
Oliver, B.G., et al., GL-036
Olivier, L., et al., WP-006
*Olsen, A.R., et al., AR-062
Olson, M.P., et al., AR-020
Olson, M.P., et al., CM-034
*OLTMANS, S.J., CM-051
OLTMANS, S.J., et al., CM-007
OLTMANS, S.J., et al., CM-031
OLTMANS, S.J., et al., CM-032
OLTMANS, S.J., et al., CM-043
OLTMANS, S.J., et al., CM-044
*OLTMANS, S.J., et al., CM-052
*OLTMANS, S.J., et al., CM-053
*OLTMANS, S.J., et al., CM-054
*OLTMANS, S.J., et al., CM-055
OLTMANS, S.J., et al., CM-059
OLTMANS, S.J., et al., PM-042
OLTMANS, S., et al., CM-049
*OORT, A.H., GF-027
OOYAMA, K.V., et al., AO-044
OPPERMAN, D.P., et al., CM-041
Orlando, J.J., et al., AL-014
ORR, B.W., et al., AP-041
ORR, B.W., et al., WP-113
ORTNER, P.B., et al., AO-020
ORTNER, P.B., et al., PM-040
*Orville, H.D., et al., AP-026
*Orville, H.D., et al., AP-027
Orville, H.D., et al., AP-038
OTTO, W.D., et al., WP-129
*OVERLAND, J.E., PM-062
OVERLAND, J.E., et al., PM-007
Owen, C.J., et al., SE-036
PACANOWSKI, R.C., et al., GF-029
Pace, M.L., et al., GL-027
Paffenhofer, G.-A., et al., GL-041
*Palmer, A.J., WP-083
*PALMER, D.R., AO-030
PALMER, D.R., et al., AO-016
*PALMER, D.R., et al., AO-031
*PALMER, D.R., et al., AO-032
*PALMER, D.R., et al., AO-033
*Palmer, D.R., et al., WP-084
*Palmer, D.R., et al., WP-085
Paneitz, C., et al., WP-107
Pap, J., et al., SE-006
Pap, J., et al., SE-028
*Pap, J., et al., SE-032
*Pap, J., et al., SE-033
Pap, J., et al., SE-044
Papen, H., et al., AR-081
Parker, E., et al., SE-015
Parker, R.L., et al., PM-038
PARRISH, D.D., et al., AL-013
PARRISH, D.D., et al., AL-030
*PARRISH, D.D., et al., AL-077
*PARRISH, D.D., et al., AL-078
PARRISH, D.D., et al., AL-094
*Parsons, C.L., et al., WP-087

*Parsons, D.B., et al., NS-036
*Parsons, D.B., et al., WP-086
*PARUNGO, F.P., et al., AR-065
PARUNGO, F.P., et al., AR-097
PARUNGO, F.P., et al., CM-076
*PARUNGO, F., et al., AR-063
*PARUNGO, F., et al., AR-064
*PARUNGO, F., et al., AR-100
PASHINSKI, D.J., et al., PM-017
PASHINSKI, D.J., et al., PM-018
Paterson, R.E., et al., CM-055
*PAULSON, A.J., et al., PM-063
*PAULSON, A.J., et al., PM-064
Paumier, J.O., et al., AR-049
*Paw U, K.T., et al., AR-101
*Pearson, G.N., et al., WP-088
PEASE, C.H., et al., PM-002
*PEASE, C.H., et al., PM-065
PEASE, C.H., et al., PM-077
Pellinen, R.J., et al., SE-037
*Perillo, G.M.E., et al., PM-066
*Periiski, L.M., et al., AL-080
*Perliski, L., et al., AL-079
*PERRY, S.G., et al., AR-066
Peteherych, S., et al., PM-081
PETERSEN, W.B., et al., AR-048
*PETERSEN, W.B., et al., AR-067
PETERSON, J.T., et al., AL-002
Peterson, M.R., et al., AL-075
Peterson, M.R., et al., AL-076
Peterson, R.E., et al., CM-054
*PHILANDER, S.G.H., GF-028
PHILANDER, S.G.H., et al., GF-004
*PHILANDER, S.G.H., et al., GF-029
PHILLIPPS, P.J., et al., GF-014
Phillips, R.S., et al., FS-034
Piazza, C., et al., WP-116
Picaut, J., et al., PM-012
Picaut, J., et al., PM-013
Picaut, J., et al., PM-037
Picaut, J., et al., PM-045
*Picaut, J., et al., PM-067
*Picaut, J., et al., PM-068
Pielke, R.A., et al., FS-027
*Pielke, R.A., et al., FS-037
Pierce, S.D., et al., AL-095
*PIERCE, T.E., et al., AR-068
*PIERCE, T.E., et al., AR-069
PIERCE, T.E., et al., AR-074
Pilipenko, V.I., et al., CM-045
Pinar, M., et al., AP-010
*Pinter, S., et al., SE-034
*PITCHFORD, M.L., et al., AR-070
PITCHFORD, M.L., et al., AR-071
Pitchford, M., et al., WP-072
Pitter, R.L., et al., AP-007
Pitter, R.L., et al., AP-008
Pitter, R.L., et al., AP-009
Pitter, R.L., et al., AP-025
*Pitter, R.L., et al., AP-028
*Pitter, R.L., et al., AP-029
*Pitter, R.L., et al., AP-030
*Pitter, R.L., et al., AP-031
Pitter, R.L., et al., AP-043
Pitts, M.C., et al., AL-082
Planet, W.G., et al., AL-002
Platt, C.M.R., et al., CM-067
Plumb, R.A., et al., GF-015
Podolske, J.R., et al., AL-022
Podolske, J.R., et al., AL-029
Podolske, J.R., et al., AL-055
Podolske, J.R., et al., AL-058
Podolske, J.R., et al., AL-085
Podolske, J.R., et al., AL-086
Podolske, J.R., et al., AL-097
Podolske, J.R., et al., AL-099
Podolske, J.R., et al., AL-106
Podolske, J.R., et al., AL-119
Podolske, J., et al., AL-098
Polkowsky, B.V., et al., AR-070
*Polkowsky, B.V., et al., AR-071
Pollock, W.H., et al., AL-047
*POOLE-KOBER, E.M., et al., AR-072
Poole, L.R., et al., AL-026
Poole, L.R., et al., AL-050
Poole, L.R., et al., AL-051
Poole, L.R., et al., AL-052
Poole, L.R., et al., AL-069
*Poole, L.R., et al., AL-081
*Poole, L.R., et al., AL-082
*Poquerusse, M., et al., SE-035
Porch, W.M., et al., AR-001
*Porch, W.M., et al., AR-102
*POSSIEL, N.C., et al., AR-073
*POSSIEL, N.C., et al., AR-074
POSSIEL, N.C., et al., AR-098
Post, M.J., et al., CM-005
POST, M.J., et al., WP-026
POST, M.J., et al., WP-033
*POST, M.J., et al., WP-089
POST, M.J., et al., WP-130
Powell, J.A., et al., AL-084
Powell, J.A., et al., AL-086
Powell, J.A., et al., AL-087
Powell, K.A., et al., AL-081
*POWELL, M.D., AO-034
*POWELL, M.D., AO-035
*POWELL, M.D., AO-036
*POWELL, M.D., AO-037
*Priegnitz, D.L., AP-032
Priegnitz, D.L., et al., AP-038
*PROCTOR, P.D., PM-069
*Proffitt, H.M., et al., AL-083
Proffitt, M.H., et al., AL-006
Proffitt, M.H., et al., AL-008
Proffitt, M.H., et al., AL-011
Proffitt, M.H., et al., AL-022
Proffitt, M.H., et al., AL-028
Proffitt, M.H., et al., AL-049
Proffitt, M.H., et al., AL-055
Proffitt, M.H., et al., AL-056
Proffitt, M.H., et al., AL-058
Proffitt, M.H., et al., AL-062
Proffitt, M.H., et al., AL-069
Proffitt, M.H., et al., AL-071
*Proffitt, M.H., et al., AL-084
*Proffitt, M.H., et al., AL-085
*Proffitt, M.H., et al., AL-086
*Proffitt, M.H., et al., AL-087
Proffitt, M.H., et al., AL-096
Proffitt, M.H., et al., AL-097
Proffitt, M.H., et al., AL-098
Proffitt, M.H., et al., AL-099
Proffitt, M.H., et al., AL-106
Proffitt, M.H., et al., AL-119
Proffitt, M.H., et al., CM-048
*PRONI, J.R., AO-038
PRONI, J.R., et al., AO-027
*PRONI, J.R., et al., AO-039
Przybylowicz, J.W., et al., AR-026
Pu, S., et al., PM-049
Purdom, J.F.W., et al., FS-020

Quayle, R.G., et al., CM-079
QUIGLEY, M.A., et al., GL-015
*QUIGLEY, M.A., et al., GL-034
*QUINN, F.H., et al., GL-035
QUINN, F.H., et al., GL-043
Quinn, P.K., et al., AL-010
Quinn, P.K., et al., PM-008
*QUINN, P.K., et al., PM-070
Raatz, W.E., et al., CM-052
*RABIN, R.M., NS-037
RABIN, R.M., et al., NS-021
*RABIN, R.M., et al., NS-038
*RABIN, R.M., et al., NS-039
*Radke, L.F., et al., CM-056
*Rahn, K.A., et al., CM-057
*Raman, S., et al., AR-075
Ramen, S., et al., AO-001
Ramen, S., et al., AO-002
RAO, K.S., et al., AR-026
RAO, K.S., et al., AR-075
*RAO, K.S., et al., AR-076
*RAO, K.S., et al., AR-077
RAO, K.S., et al., AR-090
RAO, K.S., et al., AR-096
*Rao, S.T., et al., AR-078
RAVISHANKARA, A.R., et al., AL-040
RAVISHANKARA, A.R., et al., AL-060
RAVISHANKARA, A.R., et al., AL-061
RAVISHANKARA, A.R., et al., AL-062
RAVISHANKARA, A.R., et al., AL-072
RAVISHANKARA, A.R., et al., AL-107
RAVISHANKARA, A.R., et al., AL-109
RAVISHANKARA, A.R., et al., AL-110
RAVISHANKARA, A.R., et al., AL-111
RAVISHANKARA, A.R., et al., AL-112
RAVISHANKARA, A.R., et al., AL-115
RAVISHANKARA, A.R., et al., CM-048
Ray, J.D., et al., AR-093
Ray, J., et al., AR-011
*Ray, P.S., et al., NS-040
Reddy, B.M., et al., SE-045
Reddy, P.J., et al., CM-014
Reeburgh, W.S., et al., AR-081
*REED, R.K., et al., PM-071
*REED, R.K., et al., PM-072
*REED, R.K., et al., PM-073
*REID, G.C., AL-088
*REID, G.C., AL-089
REID, G.C., et al., AL-064
*REID, G.C., et al., AL-090
*REID, G.C., et al., AL-091
Reiff, P., et al., SE-001
REINKING, R.F., et al., AP-017
*REINKING, R.F., et al., AP-033
*REINKING, R.F., et al., AP-034
REINKING, R.F., et al., AP-040
REINKING, R.F., et al., WP-049
*REINKING, R.F., et al., WP-090
*REINKING, R.F., et al., WP-091
*REINKING, R.F., et al., WP-092
*REINKING, R.F., et al., WP-093
REINKING, R.F., et al., WP-109
*Reinsel, G.C., et al., CM-058
Revercomb, H.E., et al., WP-107
Reynolds, S.D., et al., AR-010
Reynolds, S.D., et al., AR-023
Reynolds, S.D., et al., AR-082
Rhinehart, R., et al., AP-026
Rich, F.J., et al., SE-023
Richard, E.C., et al., AL-113
Richards, L.W., et al., WP-072
Richardson, I.G., et al., SE-014
*Richardson, I.G., et al., SE-036
Richardson, I.G., et al., SE-043
Richmond, A.D., et al., SE-023
*Richmond, A.D., et al., SE-037
*RIDDLE, A.C., et al., AL-092
Ridley, B.A., et al., AL-016
Ridley, B.A., et al., AL-030
Ridley, B.A., et al., AL-041
Ridley, B.A., et al., AL-042
Ridley, B.A., et al., AL-048
*Ridley, B.A., et al., AL-093
*Ridley, B.A., et al., AL-094
Ridley, B.A., et al., AL-100
Ridley, B., et al., AL-019
Ripa, P., et al., PM-057
Risch, D.A., et al., AP-011
ROACH, A.T., et al., PM-002
ROACH, A.T., et al., PM-076
ROBBINS, J.A., et al., GL-010
ROBBINS, J.A., et al., GL-011
ROBBINS, J.A., et al., GL-028
*ROBBINS, J.A., et al., GL-036
Roberts, J.M., et al., AL-013
Roberts, W.F., et al., FS-034
*Roberts, W.F., et al., FS-038
*Roberts, W.F., et al., FS-039
*Roberts, W.F., et al., FS-040
Robinette, P.A., et al., AL-012
Robinson, D.A., et al., CM-079
Roble, R.G., et al., SE-042
Rodgers, M.O., et al., AL-016
Rodgers, M.O., et al., AL-041
Rodgers, M.O., et al., AL-042
Rodgers, M.O., et al., AL-048
Rodgers, M.O., et al., AL-093
Rodgers, M.O., et al., AL-100
Rodgers, M., et al., AL-019
Rodhe, H., et al., AR-087
Rodriguez, J.M., et al., AL-056
*Rodriguez, J.M., et al., AL-095
Roelof, E., et al., SE-045
ROLPH, G.D., et al., AR-088
RONA, P.A., et al., AO-008
RONA, P.A., et al., AO-009
RONA, P.A., et al., AO-022
RONA, P.A., et al., AO-029
RONA, P.A., et al., AO-031
*RONA, P.A., et al., AO-040
*RONA, P.A., et al., AO-041
*RONA, P.A., et al., AO-042
RONA, P.A., et al., AO-051
Rood, R.B., et al., AL-022
ROSATI, A., et al., GF-008
*ROSELLE, S.J., et al., AR-079
*Rosen, J.M., et al., CM-059
Rosen, J., et al., CM-005
*Rosenfield, J.E., et al., AL-096
Rosenfield, J.E., et al., AL-099
*Rosenthal, D.A., et al., SE-038
*ROSENTHAL, S.L., AO-043
*Rosinski, J., et al., AR-080
Rosner, R., et al., SE-015
ROSSON, R.M., et al., CM-020
*Rosswall, T., et al., AR-081
*Roth, P.M., et al., AR-082
*Rothermel, J., et al., WP-130
Rottman, G.J., et al., SE-002
Rottman, G.J., et al., SE-032
Rottman, G., et al., SE-015
Rottman, G., et al., SE-028

Roux, F., et al., NS-012
Roychowdhury, U.K., et al., AL-030
Rudakov, V.V., et al., CM-045
*RUFENACH, C.L., et al., SE-039
Ruff, C., et al., WP-002
*Ruffieux, D., WP-094
Ruffieux, D., et al., WP-076
Ruffieux, D., et al., WP-077
Ruhl, E., et al., AL-113
Russell, C.A., et al., WP-058
RUST, W.D., et al., NS-021
*RUST, W.D., et al., NS-041
*Rutledge, S.A., et al., NS-042
*Rye, B.J., WP-095
Rye, B.J., et al., WP-026
Rye, B.J., et al., WP-088
Salas, L.J., et al., AL-093
Salas, L.J., et al., AL-100
*Salawitch, R.J., et al., AL-097
Salawitch, R.J., et al., AL-119
SALO, S.A., et al., PM-002
Sanders, R.W., et al., AL-018
SANDERS, R.W., et al., AL-103
SANDERS, R.W., et al., AL-104
Sanderson, T.R., et al., SE-036
*Sanderson, T.R., et al., SE-040
Sanderson, T.R., et al., SE-043
Sandholm, S.T., et al., AL-016
Sandholm, S.T., et al., AL-041
Sandholm, S.T., et al., AL-048
Sandholm, S.T., et al., AL-093
Sandholm, S.T., et al., AL-100
Sandholm, S., et al., AL-019
Sandholm, S., et al., AL-042
SANDOVAL, N., et al., AR-080
Sands, M., et al., SE-045
Sanford, L., et al., AL-036
Sanford, L., et al., AL-037
Sanhueza, E., et al., AR-081
Sarachik, E.S., et al., PM-033
Sarma, A.D., et al., WP-046
Sarmiento, J.L., et al., GF-034
Sassen, K., et al., AP-016
*Sassen, K., et al., AP-035
*Sassen, K., et al., WP-096
Sato, T., et al., AL-031
Sato, T., et al., AL-108
Sato, T., et al., AL-114
*SAUER, H.H., SE-041
SAUER, H.H., et al., SE-039
SAUER, H., et al., SE-001
Saukkonen, L., et al., NS-018
Saukkonen, L., et al., WP-023
*Savage, D.S., PM-074
Saxena, P., et al., WP-072
SAYLOR, J.H., et al., GL-016
SAYLOR, J.H., et al., GL-017
SAYLOR, J.H., et al., GL-032
SCAVIA, D., et al., GL-013
SCAVIA, D., et al., GL-015
SCAVIA, D., et al., GL-026
SCAVIA, D., et al., GL-027
*SCAVIA, D., et al., GL-045
Schanot, A.J., et al., AR-053
Schaub, M.A., et al., AR-077
SCHERE, K.L., et al., AR-069
SCHERE, K.L., et al., AR-079
SCHERE, K., et al., AR-078
Schiavon, G., et al., WP-018
SCHIERMEIER, F.A., et al., AR-051
SCHIERMEIER, F.A., et al., AR-092
Schiff, H.I., et al., AL-016
Schiff, H.I., et al., AL-019
Schiff, H.I., et al., AL-030
Schiff, H.I., et al., AL-041
Schiff, H.I., et al., AL-048
Schiff, H.I., et al., AL-093
Schimel, D.S., et al., AR-087
SCHLATTER, T.W., et al., FS-057
SCHLATTER, T.W., et al., WP-122
Schmahl, E.J., et al., SE-026
SCHMELTEKOPF, A.L., et al., AL-018
SCHMELTEKOPF, A.L., et al., AL-062
SCHMELTEKOPF, A.L., et al., AL-087
SCHMELTEKOPF, A.L., et al., AL-104
SCHMELTEKOPF, A.L., et al., AL-105
SCHMELTEKOPF, A.L., et al., AL-115
SCHMELTEKOPF, A.L., et al., CM-048
Schmidt, W., et al., SE-044
Schnell, R.C., et al., AR-065
Schnell, R.C., et al., AR-084
Schnell, R.C., et al., CM-007
Schnell, R.C., et al., CM-008
Schnell, R.C., et al., CM-031
Schnell, R.C., et al., CM-054
Schnell, R.C., et al., CM-055
Schnell, R.C., et al., CM-056
*Schnell, R.C., et al., CM-060
Schnell, R.C., et al., CM-065
Schnell, R.C., et al., CM-078
Schoeberl, M.R., et al., AL-011
Schoeberl, M.R., et al., AL-012
Schoeberl, M.R., et al., AL-022
Schoeberl, M.R., et al., AL-058
Schoeberl, M.R., et al., AL-086
Schoeberl, M.R., et al., AL-096
Schoeberl, M.R., et al., AL-097
*Schoeberl, M.R., et al., AL-098
*Schoeberl, M.R., et al., AL-099
Schoeberl, M.R., et al., AL-119
Scholer, M., et al., SE-036
*SCHROEDER, J.A., WP-097
*SCHROEDER, J.A., et al., WP-098
*SCHROEDER, J.A., et al., WP-099
SCHROEDER, J., et al., WP-010
Schubert, W.W., et al., WP-001
*SCHULTZ, P., FS-041
SCHUMACHER, J.D., et al., PM-040
SCHUMACHER, J.D., et al., PM-071
*SCHUMACHER, J.D., et al., PM-075
*SCHUMACHER, J.D., et al., PM-076
SCHWAB, D.J., et al., GL-001
SCHWAB, D.J., et al., GL-002
SCHWAB, D.J., et al., GL-003
*SCHWARTZ, B.E., FS-042
*SCHWARTZ, B.E., FS-043
*SCHWARTZ, B.E., et al., FS-044
Scott, J.F., et al., WP-116
*Scott, R.W., et al., AP-036
*Scott, R.W., et al., AP-037
Seilkop, S.K., et al., AR-020
Seilkop, S.K., et al., AR-024
SELLINGER, C.E., et al., GL-035
Senior, C., et al., SE-037
*Shabman, L., et al., GL-037
SHANAHAN, M.K., et al., CM-004
*Shang, E.C., WP-100
*Shang, E.C., et al., WP-101
*SHAPIRO, L.J., et al., AO-044
*SHAPIRO, M.A., WP-102
SHAPIRO, M.A., et al., NS-018
SHAPIRO, M.A., et al., WP-021

SHAPIRO, M.A., et al., WP-022
SHAPIRO, M.A., et al., WP-023
SHAPIRO, M.A., et al., WP-079
SHAPIRO, M.A., et al., WP-080
SHAPIRO, M.A., et al., WP-081
*SHAPIRO, M.A., et al., WP-103
*SHAPIRO, M.A., et al., WP-104
*SHAPIRO, M.A., et al., WP-105
*SHAPIRO, M.A., et al., WP-106
SHAPIRO, M.A., et al., WP-125
SHAPIRO, M.A, et al., WP-008
Shaw, G.E., et al., CM-006
Shaw, G.E., et al., CM-031
Shaw, R., et al., FS-034
Shaw, R., et al., FS-039
Shaw, R., et al., FS-040
Shaw, W.J., et al., WP-052
Shea, I.L., et al., FS-038
Sheldon, W.R., et al., AL-057
Shen, S.-H., et al., AL-059
*Sheng, J., et al., GF-030
*Sheng, J., et al., GF-031
SHEPHERD, A.J., et al., PM-053
SHEPHERD, A.J., et al., PM-056
SHEPHERD, A.J., et al., PM-080
*Sheridan, P.J., CM-061
*Sheridan, P.J., CM-062
*Sheridan, P.J., CM-063
SHERIDAN, P.J., et al., AR-065
SHERIDAN, P.J., et al., AR-084
Sheridan, P.J., et al., CM-054
Sheridan, P.J., et al., CM-055
*Sheridan, P.J., et al., CM-064
Sheridan, P.J., et al., CM-065
Shetter, J.D., et al., AL-030
Shetter, J.D., et al., AL-093
Shetter, J.D., et al., AL-094
Shetter, J.D., et al., AL-100
Shipham, M.C., et al., AL-016
Shoots, W., et al., GL-037
SHOWELL, L.C., et al., NS-041
Sibeck, D.J., et al., SE-043
*Sievering, H., et al., AR-083
*Sievering, H., et al., AR-084
*Sievering, H., et al., CM-065
Sievers, R.E., et al., AL-013
Silberstein, D.S., et al., CM-024
Sime, D.G., et al., SE-018
Simnett, G.M., et al., SE-018
Sinclair, P.C., et al., AR-034
Singer, H.J., et al., SE-014
Singh, H.B., et al., AL-016
Singh, H.B., et al., AL-093
*Singh, H.B., et al., AL-100
SIRUTIS, J., et al., GF-024
*SIRUTIS, J., et al., GF-032
*Siskind, D.E., et al., SE-042
Sistla, G., et al., AR-078
Slavin, J.A., et al. SE-014
Slavin, J.A., et al., SE-036
*Slavin, J.A., et al., SE-043
Slavin, J., et al., SE-015
*SMART, J.R., et al., FS-045
Smit, B., et al., GL-037
Smith, E.J., et al., SE-043
*Smith, J.P., et al., AL-101
Smith, M., et al., AR-098
Smith, P.L., et al., AP-006
*Smith, P.L., et al., AP-038
*Smith, P.L., et al., AP-039
Smith, P.L., et al., AP-040
Smith, P.L., et al., WP-109
Smith, S.A., et al., AL-031
Smith, S.A., et al., AL-114
Smith, S.D., et al., AL-118
Smith, S.D., et al., NS-020
*Smith, S.D., et al., PM-077
*Smith, T.L., et al., FS-046
*Smith, W.L., et al., WP-107
SMITH, Z.K., et al., SE-013
SMITH, Z.K., et al., SE-046
SMULL, B.F., et al., AO-021
SMULL, B.F., et al., NS-025
SMULL, B.F., et al., NS-036
*SMULL, B.F., et al., NS-043
SNIDER, J.B., et al., AP-035
SNIDER, J.B., et al., AP-041
SNIDER, J.B., et al., WP-001
SNIDER, J.B., et al., WP-002
SNIDER, J.B., et al., WP-009
SNIDER, J.B., et al., WP-018
SNIDER, J.B., et al., WP-032
SNIDER, J.B., et al., WP-071
SNIDER, J.B., et al., WP-091
SNIDER, J.B., et al., WP-096
SNIDER, J.B., et al., WP-113
SNIDER, J.B., et al., WP-119
SNIDER, J.B., et al., WP-120
Snodgrass, H.B., et al., SE-052
*SNOOK, J.S., FS-047
SNOOK, J.S., et al., FS-020
SNOOK, J.S., et al., FS-037
*SNOOK, J.S., et al., FS-048
Snyder, S., et al., WP-002
*SNYDER, W.H., AR-085
*SNYDER, W.H., AR-086
SNYDER, W.H., et al., AR-017
SNYDER, W.H., et al., AR-051
Sobral, J., et al., SE-045
Solimini, D., et al., WP-018
*SOLOMON, S., AL-102
SOLOMON, S., et al., AL-002
SOLOMON, S., et al., AL-018
SOLOMON, S., et al., AL-029
SOLOMON, S., et al., AL-050
SOLOMON, S., et al., AL-051
SOLOMON, S., et al., AL-052
SOLOMON, S., et al., AL-069
SOLOMON, S., et al., AL-080
SOLOMON, S., et al., AL-081
SOLOMON, S., et al., AL-082
SOLOMON, S., et al., AL-101
*SOLOMON, S., et al., AL-103
*SOLOMON, S., et al., AL-104
*SOLOMON, S., et al., AL-105
SOLOMON, S., et al., AL-113
Speer, K.G., et al., AO-041
SPELMAN, M.J., et al., GF-023
Sperry, P.D., et al., AL-037
Springer, S.R., et al., PM-012
Springer, S.R., et al., PM-013
STABENO, P.J., et al., PM-072
STABENO, P.J., et al., PM-073
STABENO, P.J., et al., PM-076
Stadler, S.J., et al., NS-039
*Stamus, P.A., et al., FS-049
STANKOV, B.B., et al., WP-079
*STANKOV, B.B., et al., WP-108
STANKOV, B., et al., WP-037
STANKOV, B., et al., WP-107
Starr, W.L., et al., AL-056
Starr, W.L., et al., AL-062

Starr, W.L., et al., AL-095
Starr, W.L., et al., AL-106
Starr, W.L., et al., CM-048
Start, G.E., et al., AR-037
Steele, L.P., et al., CM-010
Steele, L.P., et al., CM-028
Steele, L.P., et al., CM-046
*Steele, L.P., et al., CM-080
*STEHLY, G.R., et al., GL-038
*STEHLY, G.R., et al., GL-039
Stein, D.L., et al., AO-008
*Steinegger, M., et al., SE-044
Steinkamp, M.J., et al., AL-087
STENSRUD, D.J., et al., NS-039
Stephens, G.L., et al., CM-067
Stephens, G.L., et al., WP-051
Stephenson, J.J., et al., CM-002
STEPHENSON, J.J., et al., SE-007
Stevenson, J.M., et al., PM-038
Stewart, C., et al., GL-037
*Stewart, J.W.B., et al., AR-087
Stewart, R.J., et al., PM-019
Stewart, T.R., et al., FS-034
Stewart, T.R., et al., FS-039
Stewart, T.R., et al., FS-040
*Stewart, T.R., et al., FS-050
*Stewart, T.R., et al., FS-051
Stewart, T.R., et al., FS-059
Stieglitz, R.D., et al., AR-050
Stith, J.L., et al., AP-026
Stith, J.L., et al., AP-033
*Stith, J.L., et al., AP-040
Stith, J.L., et al., WP-093
*Stith, J.L., et al., WP-109
Stocker, R.A., et al., FS-037
Stockton, P.H., et al., AR-035
Stoffel, T., et al., AR-040
Stolarski, R.S., et al., AL-022
*Stone, R.S., et al., CM-066
*Stone, R.S., et al., CM-067
*STOUFFER, R.J., et al., GF-033
Strahan, S.E., et al., AL-022
Strahan, S.E., et al., AL-029
Strahan, S.E., et al., AL-055
Strahan, S.E., et al., AL-058
Strahan, S.E., et al., AL-097
Strahan, S.E., et al., AL-098
Strahan, S.E., et al., AL-099
*Strahan, S.E., et al., AL-106
Strahan, S.E., et al., AL-119
STRAUCH, R. G., et al., AL-063
STRAUCH, R.G., et al., FS-036
STRAUCH, R.G., et al., FS-057
STRAUCH, R.G., et al., WP-038
STRAUCH, R.G., et al., WP-039
STRAUCH, R.G., et al., WP-045
STRAUCH, R.G., et al., WP-067
STRAUCH, R.G., et al., WP-068
STRAUCH, R.G., et al., WP-069
STRAUCH, R.G., et al., WP-070
*STRAUCH, R.G., et al., WP-110
*STRAUCH, R.G., et al., WP-111
STRAUCH, R.G., et al., WP-122
STRAUCH, R.G, et al., WP-107
*Stumpf, G.J., NS-044
Stumpf, G., et al., NS-026
*STUNDER, B.J.B., et al., AR-088
*STUNDER, B.J.B., et al., AR-089
Sturges, W.T., et al., CM-054
*Sturges, W.T., et al., CM-068
Suess, S., et al., SE-015
Summers, S., et al., WP-059
Svensson, B.H., et al., AR-087
Swain, A.M., et al., AR-050
Swift, C., et al., WP-002
Swift, R.N., et al., WP-116
Swift, R.N., et al., WP-117
Sze, N.D., et al., AL-056
Sze, N.D., et al., AL-095
*Szoke, E.J., et al., FS-052
*SZOKE, E.J., et al., NS-045
*Szuszczewicz, E.P., et al., SE-045
Taghon, G.L., et al., AO-008
Taghon, G.L., et al., AO-042
Takahashi, T., et al., CM-069
Tallamraji, R., et al., WP-054
Tallamraju, R.K., et al., AL-065
Tallamraju, R., et al., WP-053
*Tangirala, R.S., et al., AR-090
*Tans, P.P., et al., AR-091
TANS, P.P., et al., CM-054
*TANS, P.P., et al., CM-069
*TANS, P.P., et al., CM-070
TANS, P.P., et al., CM-072
TANS, P., et al., CM-028
*Tappin, S.J., et al., SE-046
*TARAPCHAK, S.J., et al., GL-040
Tarpley, J.D., et al., CM-079
TAYLOR, A.D., et al., AR-028
*Taylor, J.A., CM-071
Taylor, J.A., et al., CM-021
Taylor, S., et al., CM-015
Tennekes, H., et al., AL-046
THACKER, W.C., et al., AO-045
*Thiele, G., et al., GF-034
Thomas, K.W., et al., NS-019
Thomas, K., et al., NS-028
Thompson, G., et al., AO-022
Thompson, R.S., et al., AR-051
THOMPSON, T.L., et al., AL-087
THOMPSON, T.M., et al., CM-009
THOMPSON, T.M., et al., CM-077
Thomson, D.W., et al., AR-044
Thomson, D.W., et al., WP-001
Thoning, K.W., et al., AR-091
Thoning, K.W., et al., CM-028
Thoning, K.W., et al., CM-070
Thoning, K.W., et al., CM-072
Thykier-Nielsen, S., et al., AR-060
Tiao, G.C., et al., CM-058
Ting, M., et al., GF-013
Ting, M., et al., GF-015
*Tobiska, W.K., SE-047
*Tobiska, W.K., SE-048
Tobiska, W.K., et al., SE-002
*Tobiska, W.K., et al., SE-049
Tognolatti, P., et al., WP-018
Togstad, W.E., et al., FS-044
TOLLERUD, E.I., et al., FS-002
*TOLLERUD, E.I., et al., FS-053
*TOLLERUD, E.I., et al., FS-054
TOLLERUD, E.I., et al., FS-058
TOLLERUD, E., et al., NS-002
*TOLLERUD, E., et al., NS-046
Toohey, D.W., et al., AL-052
Toole, J.M., et al., PM-049
Toole, J.M., et al., PM-055
Toon, G.C., et al., AL-062
Toon, G.C., et al., AL-095
Toon, G.C., et al., AL-119
Toon, G.C., et al., CM-048
Toon, O.B., et al., AL-011

Toon, O.B., et al., AL-012
Torres, A.L., et al., AL-016
Torres, A.L., et al., AL-041
Torres, A.L., et al., AL-042
Torres, A.L., et al., AL-048
Torres, A.L., et al., AL-093
Torres, A., et al., AL-019
Torres, A., et al., AL-058
Torres, A., et al., AL-062
Torres, A., et al., AL-119
Torres, A., et al., CM-048
Trainer, M., et al., AL-016
Trainer, M., et al., AL-065
Trainer, M., et al., AL-077
Trainer, M., et al., AL-078
*Trolier, M., et al., AL-107
*Tsuda, T.S., et al., AL-108
Tsuda, T., et al., AL-031
Tsuda, T., et al., AL-114
Tsurutani, B.T., et al., SE-014
Tsurutani, B., et al., SE-015
TUCK, A.F., et al., AL-008
TUCK, A.F., et al., AL-011
TUCK, A.F., et al., AL-012
TUCK, A.F., et al., AL-027
TUCK, A.F., et al., AL-043
TUCK, A.F., et al., AL-047
TUCK, A.F., et al., AL-049
TUCK, A.F., et al., AL-054
TUCK, A.F., et al., AL-055
TUCK, A.F., et al., AL-062
TUCK, A.F., et al., AL-068
TUCK, A.F., et al., AL-071
TUCK, A.F., et al., AL-083
TUCK, A.F., et al., AL-086
TUCK, A.F., et al., AL-087
TUCK, A.F., et al., AL-116
TUCK, A.F., et al., CM-048
TURET, P., et al., PM-065
TYLER, T., et al., AL-087
*Tyndall, G.S., et al., AL-109
*Tziperman, E., et al., AO-045
Uliana, E.A., et al., WP-117
*UTTAL, T., et al., AP-041
UTTAL, T., et al., WP-028
*UTTAL, T., et al., WP-112
*UTTAL, T., et al., WP-113
*Vaghjiani, G.L., et al., AL-110
*Vaghjiani, G.L., et al., AL-111
*Vaghjiani, G.L., et al., AL-112
*Vaida, V., et al., AL-113
VAN DE KAMP, D., et al., FS-057
VAN DE KAMP, D., et al., WP-122
*van Dop, H., et al., AR-092
Van Loon, H., et al., CM-037
Van Meter, A.R., et al., AR-068
*VAN VALIN, C.C., et al., AR-093
VAN VALIN, C.C., et al., AR-095
VAN VALIN, C., et al., AR-011
Vanbramer, S.E., et al., AL-048
VANDERPLOEG, H.A., et al., GL-010
*VANDERPLOEG, H.A., et al., GL-041
VANZANDT, T.E., et al., AL-031
VANZANDT, T.E., et al., AL-076
VANZANDT, T.E., et al., AL-108
*VANZANDT, T.E., et al., AL-114
Vaughan, J.M., et al., WP-130
Vay, S.A., et al., AL-048
Vedder, J.F., et al., AL-008
Vedder, J.F., et al., AL-047
Vedder, J.F., et al., AL-049
Vedder, J.F., et al., AL-055
Vedder, J.F., et al., AL-095
Vedder, J., et al., AL-100
Velden, C.S., et al., AO-014
Venkatram, A., et al., AR-092
Vervloet, M., et al., AL-067
Vesecky, J.F., et al., PM-081
Vet, R.J., et al., AR-062
VIEBROCK, H.J., et al., AR-072
Voldner, E.C., et al., AR-020
Voldner, E.C., et al., AR-062
Volz, A., et al., AL-066
von Storch, H., et al., CM-037
von Storch, H., et al., PM-048
Vongsathorn, J., et al., WP-002
Vrsnak, B., et al., SE-033
*Vukovich, F.M., et al., AR-094
*Wade, C.G., et al., WP-114
*WAGNER, W.J., SE-050
*WAGNER, W.J., SE-058
Wahner, A., et al., AL-062
*Wahner, A., et al., AL-115
Wahner, A., et al., CM-048
Waite, J.H., et al., SE-040
Waldock, J.A., et al., SE-023
Walega, J.G., et al., AL-030
Walega, J.G., et al., AL-094
*WALKER, D.C., FS-055
WALKER, D.C., et al., FS-022
*WALKER, D.C., et al., FS-056
Walker, G.O., et al., SE-045
Walko, R.L., et al., NS-007
Wallace, J.M., et al., PM-036
Wallace, J.M., et al., PM-037
Wallum, G., et al., SE-040
*Walsh, E.J., WP-115
Walsh, E.J., et al., WP-063
Walsh, E.J., et al., WP-087
*Walsh, E.J., et al., WP-116
*Walsh, E.J., et al., WP-117
*WALTER, B.A., PM-082
Wang, Y.Y., et al., WP-101
Wang, Z., et al., PM-049
Warren, L.S., et al., AL-043
Wassmann, R., et al., AR-087
*WATERMAN, L.S., et al., CM-072
WATERMAN, L.S., et al., CM-080
WATSON, A.I., et al., NS-024
Watson, J.G., et al., WP-072
Watson, J., et al., WP-078
Watson, R.T., et al., AL-003
Watson, R.T., et al., AL-004
Watson, R.T., et al., AL-005
Watson, T.B., et al., CM-060
*Watterson, I.G., et al., AL-116
Watterson, I., et al., AL-062
Watterson, I., et al., CM-048
Wayland, R.A., et al., AR-073
Weaver, J., et al., FS-034
Weaver, J., et al., FS-039
Weaver, J., et al., FS-040
WEBER, B.L., et al., AL-024
WEBER, B.L., et al., FS-057
WEBER, B.L., et al., WP-038
WEBER, B.L., et al., WP-039
WEBER, B.L., et al., WP-069
WEBER, B.L., et al., WP-111
*WEBER, B.L., et al., WP-118
WEBER, B.L., et al., WP-122
Weber, W.J., Jr., et al., GL-007
Weickmann, A.M., et al., WP-053

Weickmann, A.M., et al., WP-054
Weickmann, A.M., et al., WP-089
*WEICKMANN, K.M., et al., CM-073
*WEINSTOCK, J., AL-117
Weisberg, R.H., et al., AO-028
Wellemeyer, C.G., et al., CM-024
WELLMAN, D.L., et al., AR-012
*WELLMAN, D.L., et al., AR-095
WELLMAN, D., et al., AR-083
Wesely, M.L., et al., AR-044
Westberg, H.H., et al., AL-094
Westberg, H., et al., AR-054
*Westcott, N.E., AP-042
WESTWATER, E. R., et al., WP-099
WESTWATER, E.R., et al., WP-002
WESTWATER, E.R., et al., WP-010
WESTWATER, E.R., et al., WP-018
WESTWATER, E.R., et al., WP-107
*WESTWATER, E.R., et al., WP-119
*WESTWATER, E.R., et al., WP-120
Wetzel, P., et al., NS-039
Whipple, E.C., et al., SE-021
White, A.B., et al., WP-001
White, O.R., et al., SE-002
White, R., et al., AR-009
White, S., et al., SE-026
Whiteman, C.D., et al., AR-037
Whiticar, M.J., et al., AR-087
Wilkerson, G.W., et al., AP-011
Wilkinson, G.P., et al., SE-051
Wilkinson, P., et al., SE-045
WILKISON, S.W., et al., AR-045
Williams, E.J., et al., AL-030
Williams, E.J., et al., AL-078
Williams, E.J., et al., AL-094
*Williams, E., et al., NS-047
Williams, M.D., et al., AR-096
Williams, M.L., et al., AR-092
WILLIS, P.T., et al., AO-017
*WILLIS, P.T., et al., AO-046
Willis, R.J., et al., WP-025
Willis, R.J., et al., WP-028
*WILLOUGHBY, H.E., AO-047
*WILLOUGHBY, H.E., AO-048
*WILLOUGHBY, H.E., AO-049
*WILLOUGHBY, H.E., et al., AO-050
Willson, R.C., et al., SE-032
Wilson, J.C., et al., AL-023
Wilson, J.C., et al., AL-026
*Wilson, J.C., et al., AL-118
WILSON, J.J., et al., WP-082
*Wilson, P.R., et al., SE-051
*Wilson, P.R., et al., SE-052
Wilson, W.E., et al., WP-072
Wiltshire, J.C., et al., AO-042
Winant, C.D., et al., PM-007
Winchester, J.W., et al., CM-054
Winchester, J.W., et al., CM-055
WINEY, M.A., et al., CM-040
WINKLER, R.H., et al., AL-068
WINKLER, R.H., et al., AL-087
Wofsy, S.C., et al., AL-097
Wofsy, S.C., et al., AL-119
WOLFE, D.E., et al., WP-114
*WOLFE, D.E., et al., WP-121
*Wolter, K., CM-074
*Wolter, K., et al., CM-075
*Wolter, K., et al., CM-081
Womack, J.D., et al., AR-044
Woo, R., et al., SE-015
Woodman, R.F., et al., AL-034
WOODRUFF, S.D., et al., CM-081
Woodward, P.R., et al., NS-013
*WOOLDRIDGE, A.L., et al., AO-051
Woolf, H.M., et al., WP-107
Wright, G., et al., WP-107
*Wu, S.T., SE-053
WUERTZ, D.B., et al., FS-036
*WUERTZ, D.B., et al., FS-057
WUERTZ, D.B., et al., WP-038
WUERTZ, D.B., et al., WP-039
WUERTZ, D.B., et al., WP-069
WUERTZ, D.B., et al., WP-070
WUERTZ, D.B., et al., WP-111
WUERTZ, D.B., et al., WP-118
*WUERTZ, D.B., et al., WP-122
Xiacheng, Z., et al., AR-054
Xu, M., et al., WP-040
Xu, M., et al., WP-041
*Yamada, T., et al., AR-096
Yamamoto, M., et al., AL-108
Yang, S.J., et al., AR-097
Yang, S., et al., CM-076
Yang, W.-X., et al., AR-087
Yatteau, J.H., et al., AL-097
*Yatteau, J.H., et al., AL-119
*Yeh, T., SE-054
Yen, C.-C., et al., GL-003
Yokoi, T., et al., AL-108
Young, D., et al., WP-071
Young, K.C., et al., FS-034
Young, K.C., et al., FS-039
Young, K.C., et al., FS-040
Young, L.G., et al., AP-009
Yungel, J.K., et al., WP-116
Zaitsev, A.N., et al., SE-037
*ZAMORA, R.J., WP-123
ZAMORA, R.J., et al., WP-091
*ZAMORA, R.J., et al., WP-125
*ZAMORA, R., et al., WP-124
Zhang, R., et al., AP-025
*Zhang, R., et al., AP-043
Zhang, X.F., et al., AR-054
*Zhao, Y., WP-126
Zhong, X.P., et al., FS-044
*Zhong, X.P., et al., FS-058
Zhong, X.P, et al., FS-054
Zhou, M.Y., et al., AR-064
*Zhou, M.Y., et al., AR-097
*Zhou, M., et al., CM-076
*Zhu, X., GF-035
ZIEGLER, C.L., et al., NS-033
ZIEGLER, C.L., et al., NS-040
Zoller, W.H., et al., CM-064
*ZRNIC, D.S., NS-048
ZRNIC, D.S., et al., NS-003
ZRNIC, D.S., et al., NS-004
ZRNIC, D.S., et al., NS-014
ZRNIC, D.S., et al., NS-022
*ZRNIC, D.S., et al., NS-049
Zubrick, S.M., et al., FS-034
Zubrick, S., et al., FS-039
Zubrick, S., et al., FS-040
Zumberge, M.A., et al., PM-038
ZWICKL, R.D., et al., SE-014
ZWICKL, R.D., et al., SE-015
ZWICKL, R.D., et al., SE-036
ZWICKL, R.D., et al., SE-043
ZYREN, J.E., et al., GL-021

☆U.S. GOVERNMENT PRINTING OFFICE: 1990-573-002/21025